REPUBLIC OF THE PHILIPPINES
NATIONAL POWER CORPORATION

FEASIBILITY REPORT ON AGOS RIVER HYDROPOWER PROJECT

APPENDIX B
GEOLOGY AND CONSTRUCTION MATERIALS

MARCH 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

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FEASIBILITY REPORT

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ABBREVIATIONS AND UNIT

JICA	Japan International Cooperation Agency
NAPOCOR (NPC)	National Power Corporation of Philippines
NK	Nippon Koei Co., Ltd.
PICOREM	Presidencial Inter-Agency Committee for re-study of the Marikina River Multi-purpose Project
NEA	National Electrification Administration
MOE	Ministry of Energy
MERALCO (MECO)	Manila Electric Company
MWSS	Metropolitan Waterworks and Sewerage System
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
BPW	Bureau of Public Works
ECAFE	Economic Commission for Asia and the Far East
CDM	Camp, Dresser and McKee International, Inc.
M + E (M & E)	Metcalf and Eddy, Ltd.
$	United States Dollars
₱ (P)	Philippines Pesos
¥	Japanese Yen
FC	Foreign Currency
LC	Local Currency
EIRR	Economic Internal Rate of Return
FIRR	Financial Internal Rate of Return
O & M	Operation and Maintenance
L.F.	Load Factor

AMSL	Above mean sea level
EL.	Elevation in m AMSL
W.L. (WL)	Water level in m AMSL
H.W.L. (HWL)	High water level in m AMSL
L.W.L. (LWL)	Low water level in m AMSL
F.W.L. (FWL)	Flood water level in m AMSL
D.F.W.L. (DFWL)	Design flood water level in m AMSL
P.M.F.W.L. (PMFWL)	Probable maximum flood water level in m AMSL
mm	millimeter(s)
cm	centimeter(s)
m	meter(s)
km	kilometer(s)
m^3	cubic meter
km^2	square kilometer(s)
ha	hectare
m^3/sec (cms)	cubic meter per second
m^3/sec·month	Water volume equivalent to the discharge of 1 m^3/sec for the duration of 1 month
kg	kilogram
t (ton)	metric ton
ℓ	liter
%	percent
^oC	centigrade
o	degree
N	north
rpm	revolution per minute

Hz	Hertz (cycles per second)
kcal	kilocalorie
kV	kilovolt
kVA	kilovolt ampere
MVA	megavolt ampere
W	Watt
kW	kilowatt
MW	megawatt
kWh	kilowatt hour
MWh	megawatt hour
GWh	gigawatt hour
V	volt
BTU	British Thermal Unit

PART I GEOLOGY

CHAPTER 1

INTRODUCTION

From 1979 to 1980, a series of geological investigations was carried out in the Agos river basin, including its major upstream tributaries of the Kanan and the Kaliwa, by National Power Corporation and Japan International Cooperation Agency. This work was performed as a part of the feasibility study for the Agos Hydropower Development Project for the purpose of clarifying the geological circumstances of the project to provide one of bases to propose possible damsites on those rivers and then studying the geological conditions of the proposed damsites in more detail to enable a preliminary design of structures.

The geological investigations comprised the regional and local geological mappings, the geophysical (seismic) exploration for approximately 12 km of exploration lines, the core boring for more than 2,000 m in total length, the water pressure tests in the bore holes and the aditting in 50 m of length, as were completed by the middle of September, 1980. Based on the results of these investigations, the geological situations of the project sites are described in this report mainly in the light of foundation engineering.

CHAPTER 2

GEOLOGICAL INVESTIGATIONS

Geological investigations were carried out in two phases from June 1979 to late 1980.

The first phase of the investigation was started in June 1979 and completed for the most part in March 1980. The works performed in this phase are as follows:-

a) Regional ground investigation of the project area

b) Ground investigations of the possible damsites (Agos dam, after-bay weir, Kanan No.1, Kanan No.5) and their reservoir areas.

c) Seismic exploration of 8.2 km, core boring of 780 m/14 holes and water pressure tests in the bore holes for the Agos damsite.

d) Seismic exploration of 2.1 km, core boring of 320 m/7 holes and water pressure tests in the bore holes for the afterbay weir site.

e) Seismic exploration of 2.5 km and core boring of 10 holes and 360 m in total length for construction material sites.

In this phase in the Agos damsite, three alternative dam axes were proposed within 1 km downstream from the confluence of the Kanan and the Kaliwa, and investigations were made for all of those alternative axes. The present dam axis was selected based on the results of the above investigations and the provisional layout study of diversion tunnels, intake tunnel, power station and spillway.

For confirming the foundation conditions for the dam and the other main structures with the above layout in view, the second phase investigation was planned to execute core boring of 860 m and two test adits of 50 m each. Also in this phase, supplemental core borings of about 100 m was performed in borrow pit area.

Unfortunately the progress of boring and aditting works fell behind schedule due to the damages by typhoons and floods. As for the core borings, however, approximately 85 % of the planned works including the first and the second phase were accomplished by the middle of September, 1980, obtaining most of the necessary data. Only one test adit was completed on the right bank in this period.

Core borings were originally planned to drill 2,535 m in total length in both phases, of which 34 holes totalling 640 m were for the Agos damstie, 7 holes totalling 300 m for the afterbay weir site, 8 holes totalling 400 m for quarry sites and 13 holes totalling 195 m for borrow pit. Totally 7 units of drilling rigs were mobilized at the most busy period.

Water pressure test in the bedrock was planned on the proposed dam axis. This test was carried out for the purpose of examining permeability as well as soundness of rocks for the foundation of the damsite. Following the progress of drilling, the test was performed in bore hole on the proposed dam axes under a series of pressure of 1-4-7-10-6-2 kg/cm^2 as a rule. The test was done in the bedrock by stage of every 5 m with some exceptional cases by 3 m stage, in descending order from top to bottom of the hole. Observation of the water leakage represented by injection quantity, was done for 10 minutes in every step of pressure recording every one minute's injection rate. Calculation of coefficient of permeability and Lugeon unit was made by the following equations.

Coefficient of permeability

$$K = \frac{2.3 \times Q}{2\pi \times 60 \times L \times H} \log \frac{L}{r}$$

Lugeon unit

$$Lu = \frac{Q \times 10^3}{L \times H}$$

Where, K: Coefficient of permeability (cm/sec)

Lu: Lugeon unit

r: Bore hole radius (cm)

L: Test section length (cm)

Q: Water leakage (Injection rate) (cm^3/min)

H: Water head applied to the middle part of the test (cm)

Furthermore, correction should be made for friction loss of water head running through injection pipe. For the water pressure test, two kinds of water injection pipe were used. One of them has rather big inner diameter of 34 mm with little constriction of water passage. Accordingly, the water head loss in this pipe is deemed to be negligibly small. But the other pipe has so small diameter of 13 mm that the head loss shall be large enough to be taken into consideration.

For calculation of water head loss, we adopted the following equation derived from an experiment with 15 mm diameter injection pipe.

$$H_L = 7 \times 10^{-5} \times R_L \times Q^2$$

where, H_L: Water head loss (m)

R_L: Rod length (m)

Q: Water leakage (Injection rate) (ℓ/min)

The value of 7×10^{-5} is the friction loss coefficient.

Seismic exploration was carried out for the purpose of obtaining profiles of the foundations zoned by velocity of elastic wave propagation. Spacing of receiving points were taken at every 5 m. In exploration on the river bed, two receiving points were fixed on both banks and the shot points were set at 5 m intervals under water.

The equipments which were used for seismic exploration are as follows.

Amplifier	:	OYO Model TR-4-24 24 channels Gain, 90 dB Frequency characteristics, 5 - 3 kHz Filter, L.P.F. 15/25/45/75 Hz (± 20 %)
Oscillograph	:	OYO Model-1220 32 channels 10, 50 ms timing lines
Blaster	:	OYO High Voltage Blaster Model 1340
Geophone	:	Geo Space LRS-1000, 14 Hz

A test aditting was planned on each bank for visual observation of rock conditions in-site to be correlated with drilled cores. The dimension of each adit is about 2 x 2 m in section and 50 m in length.

The all results obtained from the above works are compiled in Data Book III in which Geological Record of Boring, Record of Water Pressure Test and Time-Distance Curve are shown.

Geological profiles are prepared by analyzing and correlating all of the above data.

The quantities of the all investigations completed as of middle of September 1980 and utilized for this report are as shown in the Table 2-1 to 2-3.

CHAPTER 3

GENERAL GEOLOGY

To the east of Manila and north of Laguna de Bay there develops a massive mountainous zone with many summits higher than 900 m above sea level, including the Sierra Madre Range which stretches parallel to and nearby the coast line of Polillo Strait. The Agos river basin is situated in the middle and eastern part of this mountainous zone and drained to Polillo Strait which is open to the Pacific Ocean.

The Kanan river, one of the two major tributaries of the Agos river, has its source in the west of the Sierra Madre Range and runs about 60 km to the south-southeast until it joins the Kaliwa river, the other major tributary, at about 21 km west of Denahican point. The Kaliwa river originates on the southern slope of the Angelo Mountains, Mount Caladang, Mount Irid and Mount Batay and flows southward at first and then eastward and finally northward running 50 km half round Mount Malabito to join with the Kanan river. Downstream from the confluence, 22 km river course, is the Agos river.

All those river channels upstream from the confluence are composed of deep narrow gorges surrounded by steep slopes rising up to high mountain ridges, whereas in the 11 km section downstream from the confluence the valley is increasingly wide open with flood plain wider than 100 m in the bottom. The lowermost 11 km of the Agos river is situated in an extensive alluvial plain.

Geologically dominant member in the above area is greywacke-conglomerate-shale alternation, which is partly associated with basic lavas and pyroclastic rocks. The age is undifferentiated, but is assumed to be from Cretaceous to Paleogene.

Geological units and structures in the project area are as described below.

3.1 Geological Units

(1) Quaternary Deposits

a) Terrace Deposits

The terraces are for the most part very recent flood terraces formed in the sides of the river channel, with several meters of height above the river bed. They are composed of silt and sand or gravels and underlain by river gravel deposits.

b) River Deposits

Deposits filling the river channel are composed of sands of various particle sizes, round to sub-round pebbles, gravels, cobbles and boulders which have been derived from volcanic rocks, greywackes, sandstone, shale, limestone and pyroclastic rocks. Limestone gravels are mainly supplied from the Kaliwa river. The river gravel deposit in the Agos river is strikingly deep as 40 meters or more, and its bottom is even lower than the present sea level in the afterbay weir site, which is deemed to reflect the past subsidence of the ground in the project area.

(2) Reef Limestone

Mount Daraitan and the hills in its vicinity on the Kaliwa river consist of massive reef limestone of Neogene. It has approximately 1.5 km of width in east-west section and elongated in the direction of north to south. This is deemed to overlie the sandstone-shale-limestone group unconformably. The limestone is white, yellowish and pinkish coloured and dense, and is distinguished from the above-mentioned older limestones by its characteristic massiveness and obscurity of beddings.

(3) Greywacke Group

This geological complex composes most part of the project area including all the proposed damsite, and is composed of the following rock units.

a) Greywacke

Greywacke is dark grey or black coloured clastic rock consisting of poorly sorted, coarse, angular to sub-angular rock fragments up to 5 mm in diameter, as well as feldspars and basic minerals, with clay and carbonates for cementing material. Majority of the component rock fragments is derived from basalt and/or andesite, except for occasional dense inclusion of limestone fragments. Effect of low grade metamorphism is often seen in chloritization. Sub-round fragments in the size of pebble to cobble of volcanic rocks and limestone are occasionally included. Also, relatively finer grained parts are encountered at places, but these parts are not clearly discerned from the other parts of rather coarse grains. The greywackes are highly consolidated and hard in fresh condition. It is remarkably massive with rather obscure beddings. Onion structures are occasionally seen in the course of weathering.

The greywackes have often appearance of pyroclastic rocks because of the component particles dominantly derived from volcanic rocks, and they can be pyroclastic rocks if those component particles of volcanic rocks were directly supplied from volcanic eruption. In this sense, the term "greywacke" may be controversial. This argument will require an extensive and detailed study in petrography and stratigraphy of this area. In this report, the term of greywacke is used following the description in Geological Map of the Philippines by Bureau of Mines (1963).

b) Calcareous Breccia

This is a facies in the greywacke group. More than 50 % of component particles are angular to sub-round pebbles of carbonate rock, with 2 to 5 mm in diameter. The other particles are similar to those in ordinary greywackes, that is, basalt and andesite fragments, feldspar, pyroxine and amphibole. Fossilized organic remains of foraminiferos and sponges are preserved in carbonate material. It is highly consolidated and hard, with carbonate veinlets.

c) Conglomerate

The greywackes occasionally contain gravels and cobbles in 5 to 30 cm of size in various densities, and the density of gravel content is fairly high in some strata. These strata are classified as conglomerate. The contained gravels and cobbles are generally of round or sub-round basic lava, pyroclastic rock and greywacke. In fresh condition, the conglomerate is also hard and massive, with little liability of separating gravels from matrix.

d) Fine Sandstone

Normal sandstone composed of rather well sorted round fine particles forms thin beds intercalating among the greywacke-conglomerate beds. It is hard and occasionally shaly.

e) Shale

Shales are dark bluish coloured homogeneous rock with high consolidation. They form thin beds, often associated with the fine sandstones, intercalating among the greywackes and the conglomerates. They are often metamorphosed in low grade and slaty. Together with the fine sandstones, their occurrences are locally limited.

f) Volcanic Rocks and Pyroclastic Rocks

These rocks of volcanic origin are rather locally intercalated in the greywacke group, and generally basic, ranging from basaltic andesite to basalt. Andesites, aphanitic or fine grained with prophilitic phenocrysts of feldspars and some chloritized, are located at places on the Kanan river. Pyroclastic rocks are also basic, with dark grey or black colour. A massive volcanic breccia bed is exposed in the downstream vicinity of the afterbay weir site. It contains densely sub-angular or sub-round fragments and blocks of andesite-basalt. Matrix is tuffaceous mudstone and sandstone, and partly lava with auto-brecciated feature.

g) Diorite

A small diorite body is observed on the Doble Creek, a tributary of the Kanan river. The diorite is medium grained with numerous feldspar laths. It appears that the diorite has intruded in the grey-wackes in the form of sill.

(4) Sandstone-shale-limestone Group

This group is exposed along the Kaliwa river in the vicinity of Daraitan and upstream. Sandstones are medium grained, homogeneous, dark bluish grey coloured hard rocks. Shales are also homogeneous, dark bluish coloured and hard. These sedimentary rocks are clearly bedded and under-gone low-grade metamorphism. Greenish charts are intercalated locally. Sandstones and shales form alternation with each unit layer up to 50 cm in thickness. Among these alternations, exist thick limestone beds, which have thickness of 1,000 m or more and are also clearly bedded. All these sandstone-shale alternations and limestones have characteristically frequent cleavages parallel to bedding planes, as well as those right angle to them, forming frequently minor shear folds. From their continuation to the greywacke group in the east of Mount Daraitan, this group is deemed to underlie the greywackes conformably.

3.2 Geological Structure

A major geological structure in this area is the Philippine Rift which has north-southerly trend through the Polillo Strait, and a major fault with left-lateral movement and relative subsidence in the east side, which forms the western border of the Rift, runs north to south at about 5 km west of Infanta, that is, eastern margin of the project area. In this vicinity the fault is almost parallel to the Sierra Madre ridge and along the coast line of Polillo Strait. It dips steeply eastward. Other faults with the similar N-S trends are observed also on the Agos and Kanan rivers and in the middle to upstream reaches of the Kaliwa river.

Some minor faults which trend NE-SW and seems to be echelon faults subordinate to the above major fault are found around the Agos and Kanan rivers. The other group of eminent faults has ENE-WSW trend, one of which runs nearly along the Agos river and terminates at the said major fault through Infanta.

Foldings show the axes stretching N-S to NE-SW, but are for the most part of minor scale. On the Kaliwa river upstream from Mount Daraitan, intensively warped minor folds are observed frequently. These are deemed to be due to the movement related with the outstanding faults with approximately N-S trends located in Mount Daraitan, San Andres and Santa Ines areas.

Whereas it is obvious that the eastern side of the Infanta fault, that is, the side of the Philippine Rift, has subsided as against the western side, it can also be said that the whole area including the western side has been subsiding generally, in view of geomorphological feature of the coast line with rather steep slopes descending directly to the sea, except for the spit of Infanta, and the thick river deposit in the downstream Agos river of which bottom is lower than the present sea level.

Bedding planes show general trend of north-south to northeast-southwest in strike and dominantly eastward dipping, in spite of frequent disturbances by faults and minor folds.

CHAPTER 4

GEOLOGY OF THE PROJECT SITES

4.1 Agos Damsite

4.1.1 General

The proposed Agos damsite is situated immediately downstream of confluence of the Kanan and the Kaliwa rivers, and the conceived dam axis is laid at 500 m of distance from the confluence.

Within about 1 kilometer's reach downstream from the confluence, the Agos river runs almost straightly east-northeastward through the channel with 120 m to 160 m of width. The river bed is at EL.40 m on the dam axis, and shows approximately 1/300 of gradient. Both banks rise at 1/1.85 to 1/2.30 (28^o to 24^o from horizontal) of average slope toward the ridges higher than EL.300 m.

On the slopes of both banks, several narrow gullies are incised at nearly right angle to the river channel. These gullies have steep gradients of 1/3.3 to 1/2.5 and a little perennial flow less than 100 litres/sec.

Bed rock in the damsite is composed of sedimentary rocks of greywacke group of Cretaceous to Paleogene age, comprising most prevailing greywackes, conglomerates, fine sandstones and shales, which have been metamorphosed in low grade. The general feature is alternating greywackes and conglomerates, with occasional intercalations of fine sandstone and shale layers. Greywacke and conglomerate form massive beds with little cleavages on bedding planes. In the other word, the bedding planes are generally obscure and is often distinguished only by the help of intercalating layers of fine sandstone and shale. The strata, showing average strike and dip of N30^o - 35^oE/ 30^o-45^oSE, develop across the river channel obliquely from upstream right bank to downstream left bank and dip toward right bank and downstream.

Joints and minor dislocation planes are developed dominantly in the direction of N70^o - 80^oW/60^o - 90^oNE.

Bed rocks are weathered in surfacial zone, and, in the uppermost zone, they are, for the most part, decomposed into residual soil. Organic top soil is rather thin, say less than 1 m.

Talus deposits composed of rock fragments and creeped residual soil are developed at the foot of the slopes along the river. Terrace of flood deposits are rather obscure in shape and very limited in locations on the said 1 km course of river around the damsite. River deposit of sand and gravels, which are derived from volcanic and pyroclastic rocks, limestones, sandstones and dominantly greywackes, has a thickness of some 30 m to 40 m. This great thickness of the river deposit is deemed partly due to the regional subsidence of ground as already mentioned.

4.1.2 Zoning of the Foundation

Geophysical (seismic) exploration in the Agos dam site, with eight exploration lines totalling 8,340 m in length, divided the ground into five zones by velocities of elastic wave propagation, which are roughly correlated with the ground conditons as follows:-

Zone I	0.2 - 0.3 km/sec	Top soil and talus
	0.3 - 0.4 km/sec	Residual soil
Zone II	0.5 - 0.7 km/sec	Residual soil/decomposed rock
Zone III	1.5 km/sec	Upper zone of river deposit
Zone IV	1.8 - 2.0 km/sec	Weathered or cracky rocks
	2.5 km/sec	Partly lower zone of river deposit
Zone V	4.5 km/sec	Fresh and solid bed rock

The above correlation is confirmed in general by core drillings, in spite of some local discrepancies in exact sense. Profile of the foundation is drawn first by determining the boundaries of each zone in accordance with the results of core drillings and then by connecting them with lines along or nearly parallel to the boundary of each velocity of seismic exploration.

The foundation consists of the following zones.

(1) Quaternary deposit

River deposit

This enormous sand and gravel deposit shows 40 m of thickness at the middle part of the river channel which is some 150 m wide. Gravels vary in size from pebble to boulder larger than 1 m in diamter and their lithic origins comprise andesite, basalt, pyroclastic rocks, limestone and the sedimentary rocks of greywacke group. Visibly with much content of large gravels, the river deposit can be supposed to have rather high strength as foundation. Though the larger part of the river deposit shows 2.5 km/sec of velocity in seismic exploration, a surfacial zone of 10 m or less thickness has only 1.5 km/sec on every exploration lines across the river. This is deemed to reflect the part of very recent and relatively looser deposits which can be movable under flood flow.

Terrace deposit

All the terraces found in the damsite are the flood terraces of recent age, which are composed of essentially the similar materials to the river deposites. This sort of terrace is formed in a narrow belt along the brink of the river as gravel deposits several meters higher than the river bed. Their shapes are not clear and often intermingled with talus deposits. In a large terrace on the right bank at the downstream bend of the river, the deposits are alternating clay and silty sand with 8 m of thickness, according to the drilling No.PS-3 and No.PS-5, and are underlain by the ordinary river gravels.

Top soil and talus

Talus deposit is the mixture of brown loam and rock fragments, which are produced by collapse and creep of the slopes of residual soil or decomposed rock. This sort of deposit is seen often at the foot of slopes and also at many places on the slopes, if not thick. Top soil is the surfacial organic soil zone, usually less than 1 m in thickness. A few minor slidings on the right bank around the seismic exploration line-B in the vicinity of the proposed dam axis are also classified in this category. On the dam axis, the top soil and talus has 5 to 10 meters of thickness on the right abutment, whereas it is only within 2 m on the left bank. Boundary between the talus and the underlying decomposed rock zone is sometimes obscure.

(2) Bed rock

Decomposed rock or residual soil

Bed rock is intensively wheathered and decomposed into the condition of residual soil. Original texture and structure of rock, joints and dislocation planes are retained. Yellowish brown coloured, it often contains blocks of hardrock, 10 to 50 cm in diameter, which have remained unweathered. These remaining rock blocks are often round due to weathering in onion structure. This zone is soft, but undisturbed and compact, with more strength as the depth increases. Sufficient strengh for foundatin of shell zone of rockfill dam, which depends also on the height of dam, can be obtained at a certain depth in this zone, if not on its surface. The zone of decomposed rock or residual soil is generally thick on the slopes on both banks. On the right bank of the damsite, it is 15 to 20 m thick in the area up to EL.120 m, as confirmed by the drillings DDH-6 and DDH-10 and the adit No.1, whereas it thins to about 10 m in the upper slope. On the left bank, it is as thick as alsmost 30 m at the foot of the slope and thins gradually up-slope to 10 m at EL.200 m. This zone is almost lacked in the river bed on the dam axis except in a little part at the end of left bank side. As this soft rock zone is not acceptable for foundation of impervious core of the fill dam, as explained in the Paragraph 4.1.5, its thickness has a significance on quantity of foundation excavation. The bottom of the decomposed rock or residual soil zone often changes gradually to the underlying weathered rock zone. However, it is also often the case that it is directly contacted with fresh rock with fairly clear-cut boundary or changes abruptly to fresh rock with thin weathered rock zone interposed in between.

Weathered rock

Though not homogeneously weathered, considerably intensive weathering is prevalent through joints, cracks and dislocation planes. Rocks on both sides of those cleavage planes are weathered and softened in various thickness, sometimes more than 10 cm, and the cleavages are often shortly spaced. Center of the rock blocks surrounded by those cleavage planes are still fresh and hard, but all of those fresh parts are separated by weathered layers, and easily detachable. Accordingly, strength of bed rock is not homogeneous and dominantly controlled by the weathered portion. In drilling, recovered core is mostly short in length or fragmental, and RQD shows 50% and less, and often less than 20%, as seen in the holes DDH-12, DDH-14, etc. On the scene of foundation preparation, the rock foundation of this condition is likely to require endless removal of loose rocks and cause uncontrollable grout leakages. This zone is deemed to have approximately 5 m of thickness under the river gravel deposit and less than 10 m on both banks, except for the upper slope of the right bank where its thickness shows some 15 m according to the drilling hole DDH-14.

Fresh rock

In the lowermost zone of fresh rock, the bed rocks are sufficiently hard and solid. Joints are generally sparse and tightly closed. The elastic wave velocity as high as 4.5 km/sec is also a proof of its hardness and solidity. Test samples from the bore hole DDH-18 in the river bed show around 600 kg/cm^2 of compressive strength. Some parts of this zone is yet slightly weathered and also some weathering and water-stain are seen on cleavage planes. These weatherings, however, does not visibly affect on the solidity of rock. This zone can obviously be a good foundation for impervious core zone of fill dam and also for concrete gravity dam. It lies 20 to 30 m deep under the slopes on both banks and 40 m under the river bed.

4.1.3 Geological Structure

Bedding planes show strikes ranging from N10°E to N50°E and dips from 20° to 45° SE, with majority of N30° - 35°E/30° - 45°SE, though they rather rarely form prominent cleavage planes. As against the dam axis, the bedding plane develops at approximately 55° to 60° of angle with downstream dip.

From geomorphological point of view, remarkable is a linear structure trending N70°E. This is represented above all by the almost straight river channel within 1 km of distance downstream from the confluence of the Kanan river and the Kaliwa river and, for another, a topographic line on the right bank which is observed in aerial photograph nearly parallel to the river and about 220 m distant from it. As for the river bed, all the seismic exploration lines across the river (Line A, B and C) picked up a low velocity zone respectively (two on the line A) and the inclined drilling DDH-18 from the brink of the left bank encountered at the depth from 110 m to 120 m, nearly in the middle part of the river, a probable fractured zone where core recovery was less than 40% as against 100% in the upper and lower sections. Obviously, it has to be taken into consideration that a fault zone with at least several meters of width does very probably exist through the bed rock under the river bed. On the other hand, as for the linear structure on the right bank, the inclined drilling DDH-10 which aimed at the structure but it revealed no major fractures. However, the seismic exploration picked up a low velocity zone on the line B which is about 30 m closer to the river than the said linear structure. This suggests another fault parallel to the river, though it can be rather minor one considering that its extension was not detected on the line A and C. Eventually, two fault lines were found out running probably in the direction of N70°E; the one in the river bed and the other on the right bank about 190 m apart from the river channel.

The other faults on dislocation planes which are observed on the outcrops and in the adit No.1 are all minor ones, mostly within several centimeter's of width associated with calcite and quartz veins and some with fractures of 30 centimeters' width at most. A few of these minor faults run nearly right angle to the river channel and the other majority trends N70° - 80°W in strike with 60° - 90°NE of dip. Though a considerable number of these minor faults are observed in the adit, they are deemed not to cause any serious difficulties in foundation treatment because of their minor scales and tightness.

Joints have also the same trends as the minor faults. The other trends of dominant frequencies are N35°E/90°, N45°E/35°SE, N75°E/60°SE, E-W/90° and N45°W/55°W. Open joints are rather sparse in fresh rock and can be easily treated by grouting. No problems are seen for the joints.

4.1.4 Permeability

Reliable data of water pressure tests were taken for a part of weathered rock zone and almost all section of fresh rock zone in the core drilling holes in the dam foundation area.

Permeability as the results of the water pressure tests is considerably varied for localities rather than for depths. The bore holes DDH-13 and DDH-14 on the right bank slope of the damsite show generally high leakages exceeding 20 Lugeon unit. Also in DDH-3 on the right bank slope downstream of the dam axis and DDH-5 at the brink of the river on the left bank, leakages are continuously more than 10 Lugeon unit. The other holes show rather low leakages less than 10 Lugeon unit and for the most part less than 5, though the sections of high leakages from 10 to 20 Lugeon unit are occasionally encountered. These high leakages, however, can be not more than the amount through open cracks in hard rock bed as observed in the drill cores which are generally of solid rocks with high R.Q.D. Therefore, these leakages can be treated by means of ordinary cement grouting without peculiar difficulties.

In the water pressure test, the pressure was increased by four steps up to 10 kg/cm^2, that is, 1 - 4 - 7 - 10 kg/cm^2, and then decreased by 2 steps, that is, 6 and 2 kg/cm^2. In more than one half of the cases, leakages are observed slightly increasing in the course of descending pressure, as against ascending pressure. This is deemed due to washing out of material filling open cracks. In the course of ascending pressure, the relation of leakage quantity and pressure is sometimes not linear and the higher rate of increase of leakage is observed in higher pressure. This can be due to deformation or increase of width of open cracks by test pressure. However, when the pressure is lowered, leakage decreases in nearly the same manner, which is deemed to suggest that the said deformation is elastic and not irreversible failure of rock. In this case, some increase of leakage in the course of descending pressure, if any, can be not only due to washing out of clay material in cracks but also due to a part of plastic deformation or creep of the rock. In the most cases in the water pressure test, no failure of rock by pressure was observed.

4.1.5 Foundation Engineering

From foundation engineering point of view, the problems in the Agos damsite are as follows:

i) Thick residual soil or decomposed rock zone on the right abutment

ii) Thick river deposit in the river bed

iii) Faults in the river bed and on the right bank

The above problems will cause considerably higher construction cost than usual, but do not imply any essential difficulties in the technical aspect. The items i) and ii) are the problem of depth of foundation excavation, and the faults in the item iii) which are several meters thick at most can be treated by ordinary procedure of excavation to several to ten meters of depth, replacement with concrete and grouting.

The foundation rocks in fresh zone are sufficiently stable and hard for both concrete gravity dam and rockfill dam. Leakages through open cleavages can be treated by ordinary cement grouting.

Basic thought for design is proposed as follows:

(1) Dam

a) Concrete gravity dam

For concrete gravity dam, the foundation excavation should be made to the fresh rock zone. Sufficient shear strength of foundation against sliding of concrete gravity dam can be obtained only in this zone. Confirmation of shear strength by in-situ rock test will be required in the future stage of investigation.

b) Rockfill dam

Foundation of impervious core zone shall be on the fresh rock zone. For the residual soil or decomposed rock zone, effect of grouting is dubious, and also there is possibility of piping through openings created by deformation of the soft foundation after the dam embankment. The weathered rock zone may have very probably difficulties of endless removal of loose rocks and uncontrollable grout leakage, and this is likely to leave the parts of insufficiently treated foundation rock in contact with the base of impervious core. In view of considerable height (more than 150 m) of the planned dam and the high water pressure created in the foundation rock as the result, it is recommended to remove the weathered rock zone at least in the river bed and a part of abutments below EL.120 m or so. Accordingly, the reliable foundation for the impervious core zone is the fresh rock zone which is 30 meter deep on the right bank, 45 meter deep in the river bed and 10 to 25 meter deep on the left bank.

Foundation of shell zone shall be placed in the residual soil or decomposed rock zone on both abutments and on the river gravel deposit in the river bed section. To remove loosened part in the surface of the decomposed rock zone, approximately 5 m of cutting from the surface of this zone is required. However, in the area where it is covered with thick top soil and talus deposit and the surfacial loosening is little, the depth of cutting in the decomposed rock zone can be reduced. In the higher parts of slopes on both banks where height of embankment is not much, say less than 30 m, the talus deposit can also be used for the foundation of shell zone. Shear strength of these zones should be confirmed by in-situ test in the stage of detailed design. River gravel deposit is deemed to be stable enough to support the dam embankment.

Except for the concrete replacement in the fault zones, the foundation treatment will be performed by cement grouting. The grouting shall be carried out for the most part from the surface of the fresh rock zone in both cases of concrete gravity dam and rockfill dam.

As already explained, parts of high leakages are rather local and often occasional. However, leakage up to 17 Lugeon unit or 2×10^{-4} cm/sec is recorded at 70 m of depth from the present ground surface and 35 m of depth from the surface of the fresh rock zone, on the dam axis (DDH-5). Conceivable depth of curtain grouting for design is 60 m from the fresh rock surface around the river bed, covering a little more than one third of the dam height and the possible high leakage portion. The depth of grout curtain shall be decreased to 30 m at the abutment of dam because of decrease of water pressure from the reservoir. Arrangement of curtain grout holes are conceived to be at 2 m intervals on two lines, to pick up every portions of high leakage.

For consolidation and blanket groutings which solidify the foundation surface and prevent pressured water through cracks from direct contact with the base of impervious earth core, the depth of 5 m will be sufficient for generally solid fresh rock. Conceivable spacing of the grout holes is 3 m.

Construction of gallery for inspection and curtain grouting was proposed at the bottom of the impervious core foundation, to be utilized for monitoring and additional treatments, if necessary, of the foundation and the grout curtain.

(2) Spillway

The conditions similar to those for the dam is applicable for foundation of spillway weir. The fresh rock zone and a part of weathered rock zone can be foundation of the weir structures. In the present design, main structures of spillway are supposed to be placed on the fresh rock zone after large cutting of the slope, and accordingly no serious problem is seen.

Deep side channels are designed on both sides of the gated spillway weir. In order to reduce the uplift pressure under the base of the side channel due to about 20 m of water head, curtain grouting to more than 20 m of depth shall be performed along the wall of the channel. However, as the surrounding rocks are generally tight enough and remarkable difference of permeability between the grout curtain zone and the surroundings is not expected, the curtain grouting will only serve to cut off local high leakage portions but will hardly be effective for lowering the pressure. Therefore, reduction of the uplift pressure will have to rely mainly on the pressure relief by drainage system to be constructed beneath the wall and slab of the side channel.

(3) Diversion Tunnel and Power Tunnel

The tunnels will pass through solid fresh rock zone for the most part of their length. Heavy support will be necessary for the decomposed and weathered rock zone in about 50 meter section from each tunnel portal. However, in view of rather frequent dislocation planes and minor faults, the support works for one third of the tunnel length through the fresh rock zone will have to be taken into consideration.

(4) Power Station

Power station can be placed on the weathered rock zone, if the rock condition is gradually changes better with depth and no soft layers are intercalated in or under the weathered rock.

4.1.6 Geology of the Reservoir Area

As the main damsite is located at the downstream vicinity of the confluence of the Kanan and the Kaliwa rivers, and the high water level be around EL.165 m, the reservoir develops to an extent of 22 km upstream along the Kanan and 28 km upstream along the Kaliwa. Situated in deep narrow gorge, the reservoir area is surrounded by high ridges. The lowest divide of the watershed in the south of Mount Daraitan has ground height of EL.320 m, yet 155 m higher than the high water level, and thickness of about 5 km at that level. Geologically, the reservoir area is situated for the most part in the greywacke-conglomerate-shale province except for the upstream part of the Kaliwa river which runs through the sandstone-shale-limestone area and the Daraitan limestone. General trend of the bedding planes shows NE-SW or N-S in strike and various degrees of eastward dip, with frequent irregularities presumably due to fault and folding. Faults are dominantly oriented NE-SW or N-S and generally not of very major scale. The latter fact, together with the considerable thickness and height of the watershed ridges, leads to elimination of fear of serious water leakage from the reservoir through faults.

The other possibility of water leakage from the reservoir is that through possible solution cavities in limestone. The limestone beds are encountered in vicinity of Daraitan near the upstream end of the reservoir in the Kaliwa river. Only a few developments of cavities have been found but the problem of leakage seems negligible because of the shallow high water level at the limestone area and the presence of other impervious beds between this area and Laguna de Bay. Existence of not a few lines of surface water streams originating higher than EL.300 m in this area can be taken as a proof of high groundwater table and imperviousness of the bed rocks.

Although the stratified limestone, exposing upstream of Daraitan, is intensely folded and has many open slits along the bedding plane, the reservoir of Agos dam does not extend to the stratified limestone area.

Whereas the bed rocks are solid enough in fresh and slightly weathered conditions, they are often very intensely weathered or decomposed into residual soil which is brown to reddish coloured clayey material. The thick residual soil is observed occasionally developing on thin ridges and gentle slopes. The thickness varies from a few meters to some 15 meters. This is only the geological member in which possibility of sliding may be conceived. However, as shown on the geological map of the reservoir area, the locations of the thick residual soil are rather limited in the high parts of the slopes that is out of the reservoir. This is presumably because it is difficult for soft materials to be retained on the steep slope in the lower part where erosion is more intensive. In consequence, the possibility of land sliding will be limited and diminished to locality.

4.2 Afterbay Weir Site

4.2.1 General

The proposed weir site is located at 8 km downstream of the Agos damsite and about 2.5 km upstream from the spot where the Agos river debouches to Infanta plane.

The left abutment of the weir is on a small hill with a saddle topography behind it, which is, however, sufficiently higher than the planned flood water level. The right bank forms rather gentle slope. The average slope gradients are about 32^{0} and 18^{0} from horizontal on the left bank and the right bank respectively. The right bank has rugged topography which is cut by small gullies.

The river bed in this site has approximately 260 m of width including a flood terrace of 8 m higher than normal river level.

Bed rock of the site is composed of the sedimentary rock, such as greywackes and conglomerates, almost similar to those in the Agos damsite. Fine sandstones and shales layers are found intercalating in the upstream of the damsite on the left bank. On the both banks, residual soil and talus deposit are developed well. Many angular rock fragments mixed with soil are present partly in the surfacial zone on the left bank.

Minor faults are observed in the conglomerates, outcropping on the left bank. These faults are not deemed so big as to displace geological structure. Far behind the damstie, a rather big fault is assumed to pass through the suddle part mentioned above. This fault, extending as far as the Agos damsite, is supposed to be a secondary fault to the Infanta fault. But according to seismic exploration, the size of the fault is deemed not so big as to affect the stability of the weir.

The bedding plane is obscure in general, except for the bedding of the intercalated thin layer of fine sandstones, showing WNW-ESE to ENE-WSW of strikes and 35^{o} to 45^{o}S of dips.

River bed deposit together with flood terrace deposit has thickness of about 50 m in the maximum, consisting of sand and gravels with the maximum diameter of more than 50 cm, which are originated mainly from greywacke and other rocks such as volcanic rocks, limestones, sandstones and conglomerates.

4.2.2 Zoning of the Foundation

Seismic exploration in the afterbay weir site was carried out with five exploration lines totalling 2,100 m in length, devided the ground into five zones by velocity of elastic wave propagation following the same procedure as in the Agos damsite. These zones are classified as follows:

Zone I	0.2 - 0.3 km/sec	Top soil and talus
Zone II	0.7 - 0.8 km/sec/ 0.9 - 1.0 km/sec	Residual soil/decomposed rock
	1.2 km/sec	Partly upper zone of river deposit
Zone III	1.7 - 1.9 km/sec/ 1.8 - 2.0 km/sec	Weathered or cracky rocks Partly lower zone of river deposit
Zone IV	2.3 - 2.5 km/sec	Lower zone of river deposit Partly weathered or cracky rocks
Zone V	3.5 km/sec/4.5 km/sec	Fresh and solid bed rock

The foundation, consisting of the almost same geological units as the Agos damsite, is divided into the following categories.

(1) Quarternary Deposit

River deposit

The recent deposit of sand and gravel layer shows about 50 m of maximum thickness and more than 250 m of width along the proposed weir axis. Gravels are composed of andesite and basaltic rocks, limestones, conglomerates and greywacke as the most abundant component. The size of gravel is more than 50 cm in maximum diameter. Superficial deposits are relatively loose, showing 0.7 - 0.8 km/sec of velocity in seismic exploration. The lower zone with 1.7 - 1.9 km/sec of the velocity seems to be compacted more densely.

Terrace deposit

The present river channel flows along the left bank side, whereas, in flood time, the river channel is divided into two flows of left and right sides, leaving sand and gravel bar in the mid stream, which is a part of flood terrace. The flood terrace is composed of essentially the same material as the river deposit. Silty sand sediments on the top of terrace deposit is cultivated as a small field. In the river bed around the afterbay weir site, several large flood terraces are developed on the both banks. The thickness of the deposit overlying the weathered bed rock is about 50 m, according to the drilling No. A2-79-3, the thickness of terrace deposit is thinner in the right bank side and thicker in the middle and the left bank side.

Top soil and talus

There is developed top soil and talus deposit on the hill slope, with thickness of 4 - 5 m on the left bank and about 10 m on the right bank. Top soil is organic with dark brown - blackish coloured. Talus deposit is composed of mixtures of soil, clay and rock fragments. On the geological map, talus deposit is shown for the area where it develops rather thick.

(2) Bed rock

Bed rock is classified into decomposed rock or residual soil, weathered rock and fresh rock according to the grade of weathering, in the same way as for the Agos damsite.

Decomposed rock or residual soil

This material, yellowish to reddish brown coloured, is associated with small rock fragments. They show thickness of 5 - 10 m in most of the core drillings. The boundary between this material and the overlaying top soil or talus is very clear because of the difference between this material and the underlaying weathered rock.

Weathered rock

Weathered rock is characterized by the development of frequent joints and cracks. These planes, generally, are stained in brownish colour and are sometimes slightly open spaced. Fresh parts of the rock still remain hard among the weathered rock zone. The thickness of this zone is about 3 - 5 m on the right bank and 15 - 35 m on the left bank. The velocity in seismic exploration for this layer is 2.5 km/sec on the left bank and 1.7 - 1.9 km/sec on the right bank. This difference seems to be due to the different grade of weathering.

In the surfacial part of the bed rock under the river bed, the weathered rock zone, of which thickness is estimated about 5 m, is confirmed by core drillings with low core recovery and also low RQD values.

Fresh rock

The elastic wave velocity of this zone is 3.5 km/sec and 4.3 km/sec. Most of joints are tightly closed except for some cracks along calcite veins, according to the drilling cores. Generally, joints are very few in deeper part.

Bed rock comprises greywacke, conglomerate and calcareous breccia. Calcareous breccias rather frequently intercalate in greywackes and conglomerates in the afterbay weir site, and are composed of brecciated limestone fragments of 2 - 5 cm in diameter with greenish matrix. Solidity and strength of the fresh rock is deemed not to present any problem for the proposed weir foundation.

4.2.3 Geological Structure

Very few bedding planes are observed in this area. On the left bank of the river bed, fine sandstone layer shows bedding plane of N80°W to N80°E in strike and 15 - 20°S in dip. This trend of the strike is different from that of the Agos damsite.

The main structural line of this area was observed on the left bank as an aerial photographic lineament in straight line with the strike of N70°E. This lineament passes through several saddle topographies, and extends to the right bank of the Agos damsite. According to seismic exploration, three low velocity zones were picked up on the left bank. The middle zone seems to coincide with this structural line. The size of this low velocity zone is estimated at about 10 m in width at most.

The other minor faults are observed at the foot of the left bank, but are deemed to have no significance for the weir foundation.

In the middle of the river bed, a 100 m wide low velocity zone is picked up. The velocity of this zone is 2.3 km/sec, that is nearly the same as the velocity of the weathered rock, i.e., 2.5 km/sec. Drilling No.A2-79-3 and A2-79-4 were performed for the purpose of detecting this low velocity zone, but no clear evidence of fault was obtained. This low velocity zone is deemed to be caused by intensive weathering and/or frequent joints.

Joint condition of this area is not clear enough because of the developed weathering. Judging from the drilling cores and the outcrops, it seems that no problems are caused by the joints because of their minor scales.

4.2.4 Permeability

Water pressure test was carried out by the same way as in the Agos damsite. On the right bank, the permeability shows relatively small values of Lugeon unit about or less than 10 in the bore holes No.A2-79-1, A2-79-2, A2-79-6 and A2-79-7. In the bore holes No.A2-79-4 on the left bank, Lugeon values are very small but they are slightly increasing in the deeper portion.

The pressure and leakage in water pressure test shows almost linear relation in general. This condition is deemed to imply solidity of the bed rock.

4.2.5 Foundation Engineering

The main problem for foundation engineering is the treatment of thick river deposit. Considering that the planned height of the weir is only 20 m above the river bed, it might be inconceivable to excavate all of the 50 m deep river deposit to put the weir base on the bed rock. In an alternative method, the base of the weir will be placed at a shallow depth in the river deposit, and the possible leakages through the river deposit under the weir body which is highly pervious but might not be effectively grouted will be controlled by long flow lines created by means of apron and/or blanket. This is also to diminish the possibility of piping. The gated part of the weir requires to be supported by piles in order to avoid the possible differential settlement of the weir body.

The foundation excavation on both abutments should be made at least into the weathered rock zone, with appropriate design of the weir sections to secure stabilities against sliding, overturning and/or piping by seepage water. Accordingly, excavation of 5 to 10 m will be required at least.

4.3 Kanan No.1 Damsite

This damsite is selected at a V section gorge about 21 km upstream from the confluence of the Kanan and the Kaliwa. The elevation of river bed is about 168 m AMSL. This gorge has parallel high cliffs on both banks for about 800 m in straight line, being composed of very hard and massive greywacke intercalated thin fine sandstone layer with pebbles and boulders of 2 to 30 cm in diameter.

Both banks form a steep cliff of nearly 45^{o} up to EL.300 m with some exposed basalts, and alternation of sandstones and shales. The general directions of the bedding plane are NS in strike and 50^{o}E to 60^{o}E in dip without any major change along the long straight river banks. The major joints are clearly observed in trend of N68^{o}E in strike and 35^{o}N in dip without open joints.

One fault was found in the upstream reaches on the left bank having N50°W in strike and a very gentle dip of 15°W accompanying with a fractured zone of about 50 cm wide. But this zone may be deep enough at the proposed dam axis.

It is judged that any type of any high dam can be supported with sufficient safety. However, a very narrow river section and very high and rapid flood at this damsite suggest us better to construct a concrete gravity dam instead of fill type dams. Concrete arch dam might be conceived for this damsite but the consideration on earthquake must be carefully paid into and geological investigations should be made for that purpose.

4.4 Kanan No.5 Damsite

This damsite was previously suggested by Lahmeyer at about 5 km upstream from the confluence of the Kanan with the Kaliwa. The river bed elevation is approximately 95 m AMSL with a width of 80 meters, narrowed by a large talus deposits from the left bank. The right bank is composed of exposed greywacke and basalts with a slope of about 30 degrees. The left bank below EL.120 m is covered with a thick talus deposits, on which local inhabitants develop farms.

The trend of bedding plane is not so clear but seems to be N30°E in strike and 50°E in dip. A fault lies on the bed of small gully on the left bank slope, having N23°E in strike and 48°W in dip accompanying with 10 to 30 cm thick fractured zone. A small gully on the right bank stretches straightly and joins down the Kanan in a sharp angle of about 40 degrees, which suggests existence of another fault. Joint sets of this site develop in various directions and most joints were filled up with calcite vein.

It is judged that the rock formation are the same as those of Agos damsite and sound enough for dam foundation, but the weathered rocks and talus deposits on the left bank may be considerably deep, so that much quantity of excavation may be required and dam volume will be nearly the same as the Agos dam.

4.5 Construction Material Source

4.5.1 Quarry Site

A quarry site for the Agos dam was selected in the area around a small stream which flows into the Kaliwa river from its left bank at about 500 m upstream from the confluence of the Kaliwa and the Kanan rivers. The distance from the Agos damsite is only 2 km. The stream runs straightly for about 3 km from northwest to southeast and the slopes on both banks with approximately 30 degrees of inclination from horizontal have almost straight and parallel contour lines up to EL. 400 m.

According to the results of core drillings at four spots which have been so far completed, coverings of talus, residual soil and weathered rock zone are in the range of 5 to 12 meters to the fresh rocks. In the bore hole Q-A1-4, the condition is exceptionally unfavourable with fresh rock at 27 m of depth. These thick overburdens are, however, the conditions in the higher parts or at the top of the slopes where the drillings were carried out, and the fairly hard rocks are exposed or covered with very thin talus deposit on the middle and lower parts of the slopes. Even if excluding the vicinity of the bore hole Q-A1-4, approximately 8 million cubic meters are at least obtained in this area. Further 5 million cubic meters will be obtained from the spillway excavation.

A quarry site for the afterbay weir site was proposed in the area located on the left bank of the weir site. The area faces to the Agos river with steep slope, with 40^{o} - 60^{o} inclination from horizontal and about 50 m of height. Above this steep slope, rather wide gentle slope of 15^{o} - 30^{o} inclination is developed toward the north.

In this area, two bore holes are located but the result was not obtained yet by the middle of September 1980. In small gullies, developing in this area, massive conglomerates intercalated by this fine sandstone layers are found.

For the Kanan No.1 dam and the Kanan No.5 dams, the quarry rocks of the greywacke group with sufficient hardness will be easily obtained in the vicinities of the damsite.

4.5.2 Borrow Pit

Possible source of impervious core material for rockfill dam is the residual soil in the vicinity of the damsites. Core borings with standard penetration test in a proposed borrow pit upstream of the Agos damsite show that the residual soil is 5 to 10 m thick, and so the same thicknesses are assumed in the other proposed borrow pits downstream of the Agos damsite and in the vicinity of the afterbay weir site. It may be required for the generally very clayey residual soil to be mixed with coarser materials from the underlying transition zone from decomposed rock to weathered rock. Detailed accounts of these materials are given in Part II of this report.

It seems that no favourable borrow pit exist in the vicinity of the Kanan No.1 damsite because the general topography is so steep that most of the residual soil or other overburdens seem to have been eroded away. This can be the secondary reason to recommend concrete gravity dam for this site.

For the Kanan No.5 dam, sufficient material seems to be expectable from the gentle slope on the left bank of the Kanan river and from the talus deposits and the terraces along the river as well.

For the material source for the damsites on the Kanan river, further investigations in detail will be required in the future.

CHAPTER 5

STUDY OF SEISMIC COEFFICIENT FOR DAM

The available record of earthquakes in the Philippines covers the years since 1585. The present analysis, however, utilizes only the records from 1915 to 1976, which have reliable descriptions on approximate locations of the epicenters and, though not all, on magnitudes.

Equations used for the analysis are as follows:

- Kawasumi's formula

$$I_j = M_k - 0.00183(d - 100) - 4.605 \log\frac{d}{100} \quad \text{(when } d \geq 100 \text{ km)} \ldots(1)$$

$$I_j = M_k + 4.605 \log\frac{Do}{D} + 2k\,(D - Do) \log e \quad \text{(when } d < 100 \text{ km)} \ldots(2)$$

where, I_j: Intensity in JMA (Japan Meteorological Agency) scale

M_k: Magnitude in Kawasumi's scale, that is, JMA intensity at the distance of 100 km from the epicenter. (Magnitude in Richter scale $M = 4.85 + 0.5\,M_k$)

d: Distance from the epicenter (km)

D: Distance from the focus (km)

Do: Distance from the focus to the point of d = 100 km

k: Damping rate of S-wave (0.0192/km)

In the said record, intensity is given in Rossi-Forel Scale. For the calculation in the above equations, it was correlated with JMA intensity by comparison of descriptions for each grade of the intensity in both scales.

The analysis is made in the following procedure.

For all the earthquakes in the record, intensities that could be felt at the damsite are calculated by the Kawasumi's formula. In case that the intensity at Infanta is recorded, it is taken for the intensity at the damsite. In case that the record shows only intensities felt at some places and not magnitude, the magnitude is estimated by the formula as shown in parenthesis on the List of Earthquakes, and then the possible intensity at the site is calculated.

Intensity

Rossi-farel Scale	JMA Scale
I	0
II	0.7
III	1.3
IV	1.7
V	2.3
VI	3.0
VII	3.7
VIII	4.7
IX	more than 4.7

Frequency of earthquakes in each grade of JMA intensity, within 61 years from 1915 to 1970, is converted into frequency in 100 years, and from the relation between the intensity (I_j) and the cumulative number of frequency (Nc), the expected maximum intensity and hence the expected maximum acceleration in a probable return period of 100 years are obtained.

Earthquake Intensity and Frequency

Intensity (I_j)	Frequency in 61 years	Frequency in 100 years	Cumulative number for 100 years (Nc)
0 (less than 0.6)	26	42.62	190.16
1 (0.6 - 1.5)	54	88.52	147.54
2 (1.6 - 2.5)	28	45.90	59.02
3 (2.6 - 3.5)	6	9.84	13.12
4 (3.6 - 4.5)	0	0	3.28
5 (4.6 - 5.5)	1	1.64	3.28
6 (5.6 - 6.5)	1	1.64	1.64
Total	116	190.16	

Plotting the above on the I_j - log Nc coordinates, and by the minimum square method, the relation between I_j and Nc is given as below.

$$\log Nc = 2.378 - 0.384 I_j$$

For the case of Nc = 1, the expected maximum intensity in a probable return period of 100 years is obtained as $I_j = 6.2$. This value is nearly equal to the intensity of the earthquake in August 1937 which had epicenter within 10 km and magnitude of 7.5.

According to Kawasumi, the relation between the intensity I_j and the maximum acceleration α of the earthquake motion is very closely approximated by the relation

$$\alpha = 0.45 \times 10^{0.5 I_j} \text{ (gal)}$$

where α is the geometrical mean value of α as observed empirically. Accordingly, the expected maximum acceleration in a probable return period of 100 years is 566 gal or 0.58g.

Practically, such a large value is not taken for design, because the maximum acceleration of an earthquake motion will act only for a fraction of a second so that it cannot cause such significant deformation as expected when it is assumed to be a lasting static force.

Most engineers in the United States, who use a pseudo-static method of seismic stability analysis, adopt some empirical value for the design seismic coefficient; generally, this value is in the range of 0.05 to 0.15 (H. Bolton-Seed & G.R. Martin, 1966). Japanese National Committee on Large Dams proposed a design criteria for dams (1971), which prescribes the ground seismicity coefficient to be in the range of 0.12 to 0.20 for concrete and rockfill dams in the seismically active region in the Japanese archipelago where the 100 year acceleration is in the range of 200 to 600 gals. There is no definitive logical basis for selecting those design value but for the experience that numerous dams have been constructed by the use of seismicity coefficients within the said range without any serious damages.

Considering the resemblance of seismic situation between the Philippines and Japan, recommendable design value for the ground seismicity coefficient is 0.15 to 0.20.

TABLES

Table 2-1 <u>Quantity of Core Boring (1/2)</u>

Location	Hole No.	Inclination of Hole	Scheduled Depth	*Completed Depth	Number of W.P.T.	Remark
Agos damsite (including spillway and headrace intake)	DDH-1 (A1-79-1)	Vertical	50.0 m	50.0 m	8	
	DDH-2	"	70.0	70.0	10	
	DDH-3	"	50.0	50.0	10	
	DDH-4	"	50.0	50.0	9	
	DDH-5	"	70.0	70.0	7	
	DDH-6	"	50.0	50.0	4	
	DDH-7	"	50.0	50.0	7	
	DDH-8	"	70.0	70.0	4	
	DDH-9	"	50.0	50.0	7	
	DDH-10	60° to S16°E	70.0	70.0	-	W.P.T was not conducted
	DDH-11	Vertical	50.0	50.0	8	
	DDH-12	"	50.0	70.0	7	
	DDH-13	"	50.0	50.0	11	
	DDH-14	"	50.0	50.0	8	
	DDH-15 (A1-80-1)	"	30.0	30.0		
	DDH-16	"	50.0	50.0		
	DDH-17	"	50.0	50.0		
	DDH-18	60° to S28°E	100.0	123.0		
	DDH-19	Vertical	40.0	48.3		drilling is not yet completed
	DDH-20	50° to N28°W	100.0	45.0		
	DDH-21	Vertical	40.0	40.0		
	DDH-22	"	40.0	40.0		
	DDH-23	"	40.0	40.0		
	DDH-24	"	50.0	50.0		
	DDH-25	"	30.0	30.0		
	DDH-26	"	40.0	25.0		
	DDH-27	"	30.0	30.0		
	DDH-28	"	30.0	30.0		
	DDH-29	"	30.0	30.0		
	Subtotal		1,480.0			
Agos damsite (Surge tank, penstock, powerhouse site)	PS-1	Vertical	80.0 m	80.0 m		
	PS-2	"	30.0	30.0		
	PS-3	"	25.0	66.0		
	PS-4	"	-	-		drilling of this hole is cancelled
	PS-5	"	25.0	55.0		
	Subtotal		160.0	231.0		

*Actual Progress by September 15, 1980

Table 2-1 Quantity of Core Boring (2/2)

Location	Hole No.	Inclination of Hole	Scheduled Depth	*Completed Depth	Number of W.P.T.	Remark
Afterbay weir site	A2-DDH-1 (A2-79-1)	Vertical	40.0^{m}	40.0^{m}	5	
	A2-DDH-2	"	40.0	40.0	5	
	A2-DDE-3	"	40.0	60.0	-	W.P.T was not conducted
	A2-DDH-4	"	40.0	40.0	7	
	A2-DDH-5	"	50.0	50.0	6	
	A2-DDH-6	"	40.0	40.0	4	
	A2-DDH-7	"	50.0	50.0	6	
	Subtotal		300.0	320.0		
Quarry site (Agos dam)	Q-A1-1	Vertical	50.0^{m}	m		
	Q-A1-2	"	50.0	50.0		
	Q-A1-3	"	50.0	50.0		
	Q-A1-4	"	50.0	50.0		
	Q-A1-5	"	50.0	50.0		
	Q-A1-6	"	50.0			drilling of this hole is cancelled
Quarry site (weir site)	Q-A2-1	"	50.0			
	Q-A2-2	"	50.0			
	Subtotal		400.0			
Borrow pit (scheduled in 1979)	B-1	Vertical	15.0^{m}	11.05		
	B-2	"	15.0	15.30		
	B-3	"	15.0	11.20		
	B-4	"	15.0	5.00		
Borrow pit (scheduled in 1980)	B-5	"	15.0	10.66		
	B-6	"	15.0	15.00		
	B-7	"	15.0	15.28		
	B-8	"	15.0	15.00		
	B-9	"	15.0	11.75		
	B-10	"	15.0	10.35		
	B-11	"	15.0	5.60		
	B-12	"	15.0	6.35		
	B-13	"	15.0	9.60		
	Subtotal		195.0	142.14		
	Total		2,535.0			

Table 2-2 Quantity of Seismic Exploration

Location	Exploration line	Length	Remark
Agos damsite	I - A	1,300 m	
	I - B	1,600	
	I - C	1,200	
	I - D	1,300	
	I - E_1	500	
	I - E_2	900	
	I - E_3	300	
	I - F	1,100	
	Subtotal	8,200	
Afterbay weir site	II - A	750	
	II - B	500	
	II - C	250	
	II - D	300	
	II - E	300	
	Subtotal	2,100	
Quarry site	Q - A	600	Agos No.1 quarry site
	Q - B	500	"
	Q - C	900	"
	Subtotal	2,000	
Borrow pit	B - A	300	Agos No.1 borrow pit
	B - B	200	"
	Subtotal	500	
	Total	12,800	

Table 2-3 Quantity of Test Adit

	Adit No.	Scheduled Length	*Completed Length
Agos damsite (Right bank)	AD - 1	50.0 m	50.0 m
Agos damsite (Left bank)	AD - 2	50.0	3.0

Table 5-1 List of Earthquakes (1/3)

No.	Date		Epicenter Latitude N	Epicenter Longitude E	Magnitude	Distance from site to Epicenter	Intensity felt at the site (Ij)	Notes
1	1915	Mar 12	12.5°	124°	7.0	351 km	1.3	
2	1919	Mar 21	13°	123°	6-1/2	237	1.3	
3	1925	May 25	12.5°	122.5°	6-1/2	234	1.4	
4	1927	Apr 13	16°	120.5°	6-1/2	186	1.9	
5	1928	Jun 15	12.5°	121.5°	7.0	226	2.4	
6		Aug 05	16°	119.5°	6-1/2	260	1.2	
7	1931	Oct 28	17.5°	121.5°	6-1/4	320	0.1	
8	1932	Aug 24	16.5°	120.5°	6-1/4	234	0.9	
9	1933	Mar 03	15.5°	120°	6-1/2	186	1.9	
10		Jun 06	14°	120°	6-1/4	171	1.6	
11		Sep 21	13°	121°	6-1/2	180	2.0	
12	1934	Feb 14	17.5°	119°	7.6	411	2.1	
13		Nov 26	14°	120°	6-1/4	171	1.6	
14	1935	Feb 08	13.5°	122.5°	6.0	160	1.3	
15	1936	May 20	13.5°	121.5°	6.0	120	1.9	
16	1937	Aug 20	14.5°	121.5°	7-1/2	9	6.1	
17	1938	Feb 05	14°	124°	6-1/2	274	1.0	
18		May 23	18°	119.5°	7	429	0.8	
19	1939	May 07	13.5°	121.5°	6-1/2	120	2.9	
20	1940	Mar 28	14.5°	120°	6-3/4	157	2.8	
21	1942	Apr 08	13.5°	121°	7.7	129	5.1	
22	1947	Jun 08	11.5°	125°	6.9	500	0.1	
23	1948	Jan 25	10.5°	122°	8.2	450	3.1	
24		Mar 03	18.5°	119°	7.2	500	0.7	
25	1949	Feb 15	13°28'	120°45'	(6-1/4)	146	2.0	
26		Mar 28	13°52'	120°00'	(6.0)	194	0.8	
27		Mar 28	13°52'	120°00'	(6-1/2)	194	1.8	
28		Mar 28	13°52'	120°00'	(6.0)	194	0.8	
29		Aug 05	15°50'	121°45'	(5-1/2)	109	1.1	
30		Sep 05	16°50'	123°15'	(6-1/4)	283	0.4	
31		Dec 29	17°00'	121°38'	7.4	271	2.8	
32	1950	Jan 03	17°00'	121°38'	6.5	271	1.0	
33	1951	Apr 30	16°20'	122°45'	(6.0)	237	0.5	
34		Jul 03	14°48'	123°12'	(5-3/4)	188	0.3	
35		Sep 07	15°36'	120°52'	(5-1/2)	129	0.7	
36	1952	Mar 19	9°25'	125°30'	7.5	734	0.2	
37	1954	Jul 02	13°00'	124°00'	(6-1/2)	314	0.5	
38	1955	May 16	13°20'	122°40'	(5-3/4)	188	0.2	
39		Nov 15	15°40'	120°15'	(6.0)	174	1.0	
40	1956	May 05	15°45'	122°00'	(5-1/2)	140	0.6	
41		Jul 20	15°20'	119°20'	(6-1/2)	240	1.2	
42		Oct 23	14°05'	120°25'	(5-3/4)	129	1.3	
43		Oct 27	14°20'	123°35'	(6-3/4)	229	1.7	
44		Oct 28	14°20'	123°35'	(6-3/4)	229	1.7	

Note: Magnitude in parenthesisis not in the original record, but calculated from intensity in the vicinity.

Table 5-1 List of Earthquakes (2/3)

No.	Date	Epicenter Latitude N	Epicenter Longitude E	Magnitude	Distance from site to Epicenter	Intensity felt at the site (Ij)	Notes
					km		
45	1956 Nov 10	15°45'	120°15'	(5-3/4)	183	0.4	
46	Nov 16	14°20'	123°35'	(6-1/2)	229	1.3	
47	1957 Dec 24	13°00'	121°00'	(5-3/4)	180	0.5	
48	1958 Jan 20	14°05'	120°12'	(6.0)	146	1.5	
49	Feb 19	15°30'	121°00'	(5-1/4)	114	0.7	
50	Apr 15	15°25'	119°00'	(6-3/4)	280	1.2	
51	Nov 13	15°30'	122°10'	(5-3/4)	129	1.3	
52	1959 Jul 19	15°30'	120°20'	(6-3/4)	157	1.9	
53	1960 Jan 29	14°00'	120°00'	(6.0)	171	0.8	
54	Dec 15	13°36'	120°42'	(5-1/2)	137	0.8	
55	Dec 15	13°36'	120°42'	(5-1/2)	137	0.8	
56	Dec 24	15°15'	121°40'	(5-1/2)	77	1.5	
57	1961 Feb 27	16°00'	121°36'	(5-3/4)	160	0.7	
58	Jun 19	12°36'	121°54'	5.8	220	0.1	
59	Jul 01	16°20'	121°45'	(6-1/4)	194	1.3	
60	Jul 15	13°06'	120°24'	(6-1/4)	197	1.2	
61	1963 Feb 26	15°30'	121°18'	5.0	103	0.7	
62	Oct 22	14°10'	122°10'	(5-3/4)	89	1.6	
63	1966 Jan 10	13.9°	120.1°	5.5	166	0.2	
64	Feb 17	15.6°	121.9°	(5-1/2)	126	0.8	
65	Aug 15	13.4°	121.5°	5.7	129	0.7	
66	Dec 21	14.3°	122.1°	5.4	74	2.0	
67	1967 Jul 31	15.8°	121.4°	(5-3/4)	134	1.1	
68	Sep 11	14.8°	121.4°	(5-1/2)	26	2.1	
69	1968 Aug 02	16.5°	122.3°	7.3	228	3.0	
70	Aug 02	16.6°	122.0°	(6-1/2)	231	1.6	
71	Aug 03	16.5°	122.3°	5.9	228	0.2	
72	Aug 11	15.5°	121.6°	5.4	106	0.9	
73	Aug 14	15.1°	122.5°	5.4	126	0.6	
74	Aug 23	15.6°	121.5°	5.2	114	0.4	
75	Aug 28	15.2°	122.6°	(6-1/4)	140	2.1	
76	Aug 30	15.9°	121.7°	5.2	137	0.7	
77	Sep 23	15.7°	121.9°	5.3	134	0.3	
78	Nov 22	16.3°	122.3°	5.3	209	1.3	
79	Nov 22	13.1°	122.6°	(6-1/4)	186	1.6	
80	Dec 29	13.6°	120.6°	(5-1/2)	143	0.5	
81	1969 Mar 13	16.1°	122.2°	(6-1/4)	189	1.3	
82	Mar 26	16.1°	122.2°	(6-1/4)	189	1.3	
83	May 15	16.1°	121.9°	5.2	177	1.7	
84	Jun 11	13.2°	121.4°	5.4	151	0.2	
85	Dec 23	13.8°	120.6°	5.3	126	0.4	
86	1970 Feb 06	12.6°	122.2°	6.1	231	0.6	
87	Feb 26	13.6°	120.6°	5.3	143	0.1	
88	Apr 07	15.8°	121.7°	6.4	134	2.5	

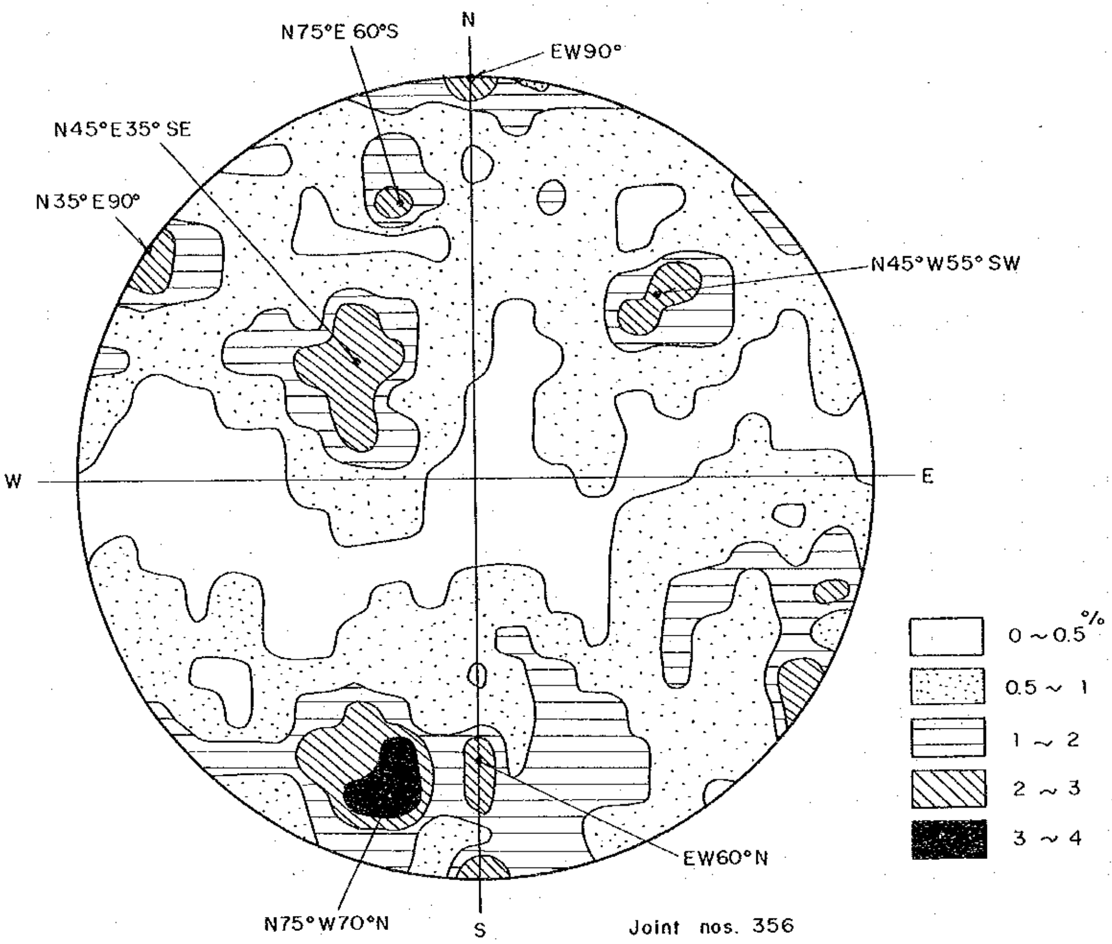
Note: Mangitude in parenthesisis not in the original record, but calculated from intensity in the vicinity.

Table 5-1 List of Earthquakes (3/3)

No.	Date	Epicenter Latitude N	Epicenter Longitude E	Magnitude	Distance from site to Epicenter	Intensity felt at the site (Ij)	Notes
89	1970 Apr 07	15.7°	121.8°	(6-1/4)	131	2.2	
90	Apr 08	15.3°	121.6°	5.2	80	1.3	
91	Apr 08	15.4°	121.7°	(6.0)	100	2.2	
92	Apr 09	15.4°	121.8°	5.7	100	1.7	
93	Apr 12	15.1°	122.1°	5.9	89	2.3	
94	Apr 12	14.1°	122.0°	5.5	77	1.4	
95	Apr 15	15.1°	122.7°	5.7	143	0.9	
96	May 01	15.7°	121.8°	5.5	131	1.3	
97	Jul 11	13.9°	120.4°	5.6	134	0.9	
98	Aug 20	15.5°	121.5°	(5-1/2)	100	1.1	
99	Nov 13	15.0°	120.1°	(5-1/4)	151	0.1	
100	1971 Jul 04	15.6°	121.9°	5.5	126	1.7	
101	Jul 20	15.3°	120.3°	5.4	149	0.2	
102	1971 Mar 16	15.7°	121.8°	5.1	131	1.3	
103	Apr 26	13.4°	120.3°	6.2	180	1.4	
104	Apr 27	13.5°	120.7°	5.4	140	0.4	
105	May 22	16.1°	122.3°	5.7	186	0.3	
106	1973 Mar 17	13.4°	122.8°	7.0	191	2.8	
107	Aug 18	11.5°	121.4°	(6-1/2)	337	0.2	
108	Oct 25	13.6°	120.2°	(6.0)	171	1.0	
109	Nov 21	13.5°	121.0°	(5-1/2)	129	0.6	
110	1974 Feb 19	13.9°	122.3°	5.7	114	1.4	
111	May 03	15.7°	121.7°	(6.0)	140	1.7	
112	1975 Jun 18	13.9°	120.6°	5.4	117	0.8	
113	Oct 05	14.2°	121.9°	5.0	60	0.5	
114	1976 Feb 13	15.67°	121.703°	5.4	137	1.7	
115	Feb 13	13.91°	120.1°	5.6	166	0.4	
116	Jun 07	14.1°	124.8°	6.7	354	0.7	

Note: Magnitude in parenthesisis not in the original record, but calculated from intensity in the vicinity.

F I G U R E S



(Polar's points of joint planes are plotted on the lower hemisphere.)

Fig. 4 -1 Equal Area Stereographic Projection for the Frequency of Joint Direction

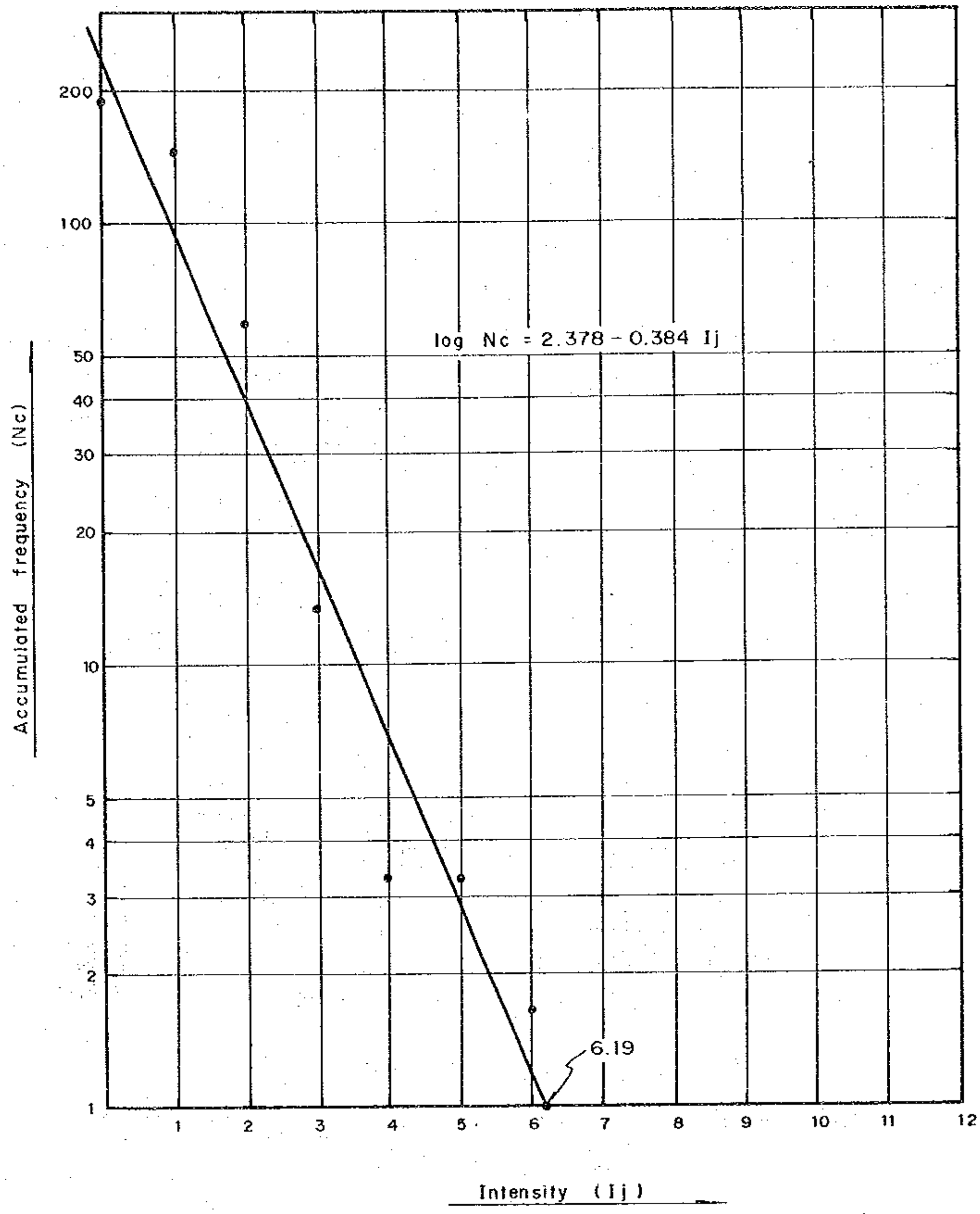


Fig. 5 - 1 The Relation between Accumulated Frequency and Intensity of the Earthquake

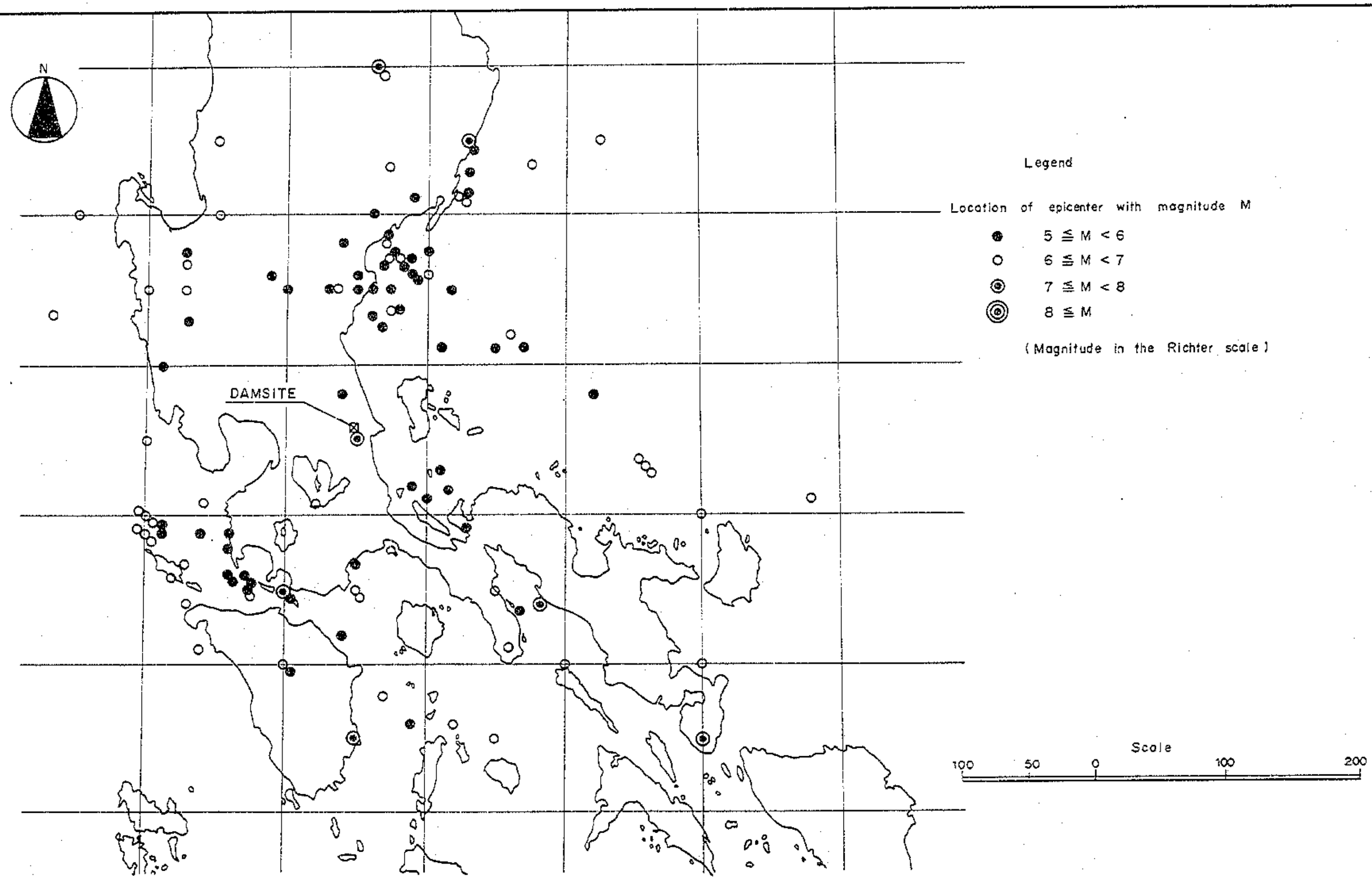
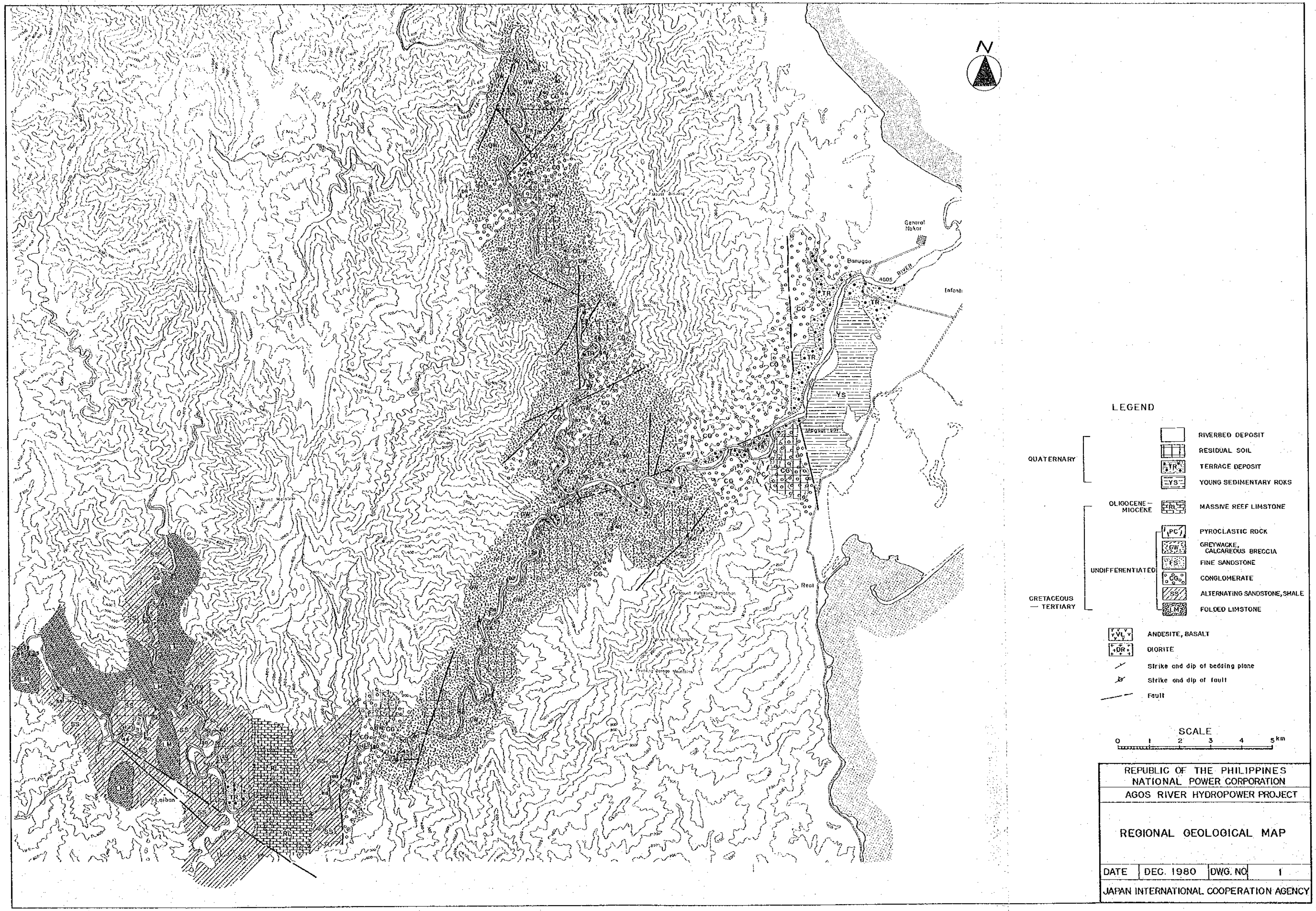
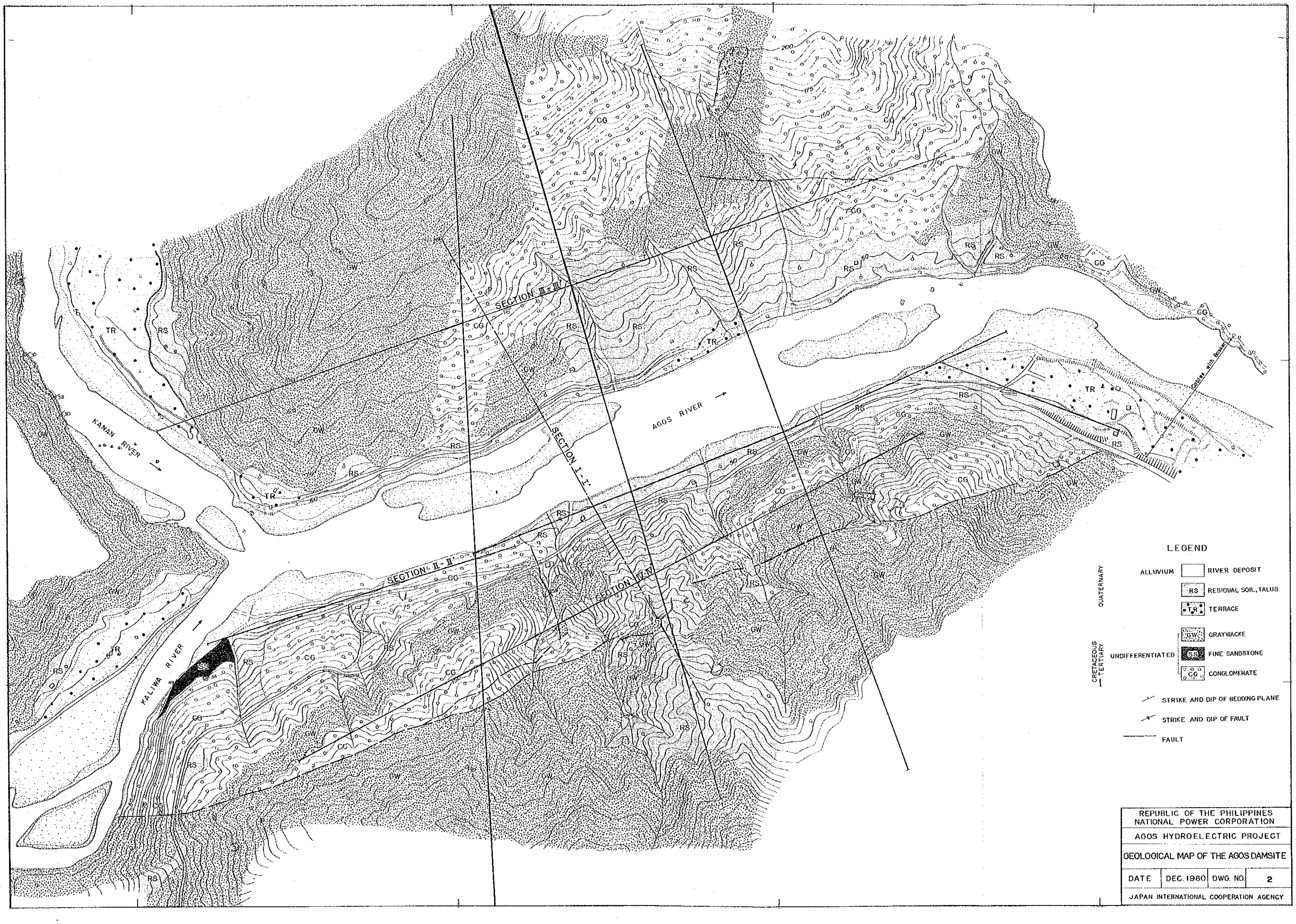


Fig. 5-2 Distribution of Epicenters of Earthquakes (1915-1976) which were influential to the project site

DRAWINGS



N
General Nakar
Banugao
AGOS RIVER
TR
YS
CG
GW
SS
LM
RL
Real
LEGEND
QUATERNARY
RIVERBED DEPOSIT
RESIDUAL SOIL
TERRACE DEPOSIT
YOUNG SEDIMENTARY ROKS
OLIGOCENE — MIOCENE
MASSIVE REEF LIMSTONE
CRETACEOUS — TERTIARY
UNDIFFERENTIATED
PYROCLASTIC ROCK
GREYWACKE, CALCAREOUS BRECCIA
FINE SANDSTONE
CONGLOMERATE
ALTERNATING SANDSTONE, SHALE
FOLDED LIMSTONE
ANDESITE, BASALT
DIORITE
Strike and dip of bedding plane
Strike and dip of fault
Fault
SCALE
0 1 2 3 4 5 km
REPUBLIC OF THE PHILIPPINES
NATIONAL POWER CORPORATION
AGOS RIVER HYDROPOWER PROJECT
REGIONAL GEOLOGICAL MAP
DATE DEC. 1980 DWG. NO 1
JAPAN INTERNATIONAL COOPERATION AGENCY



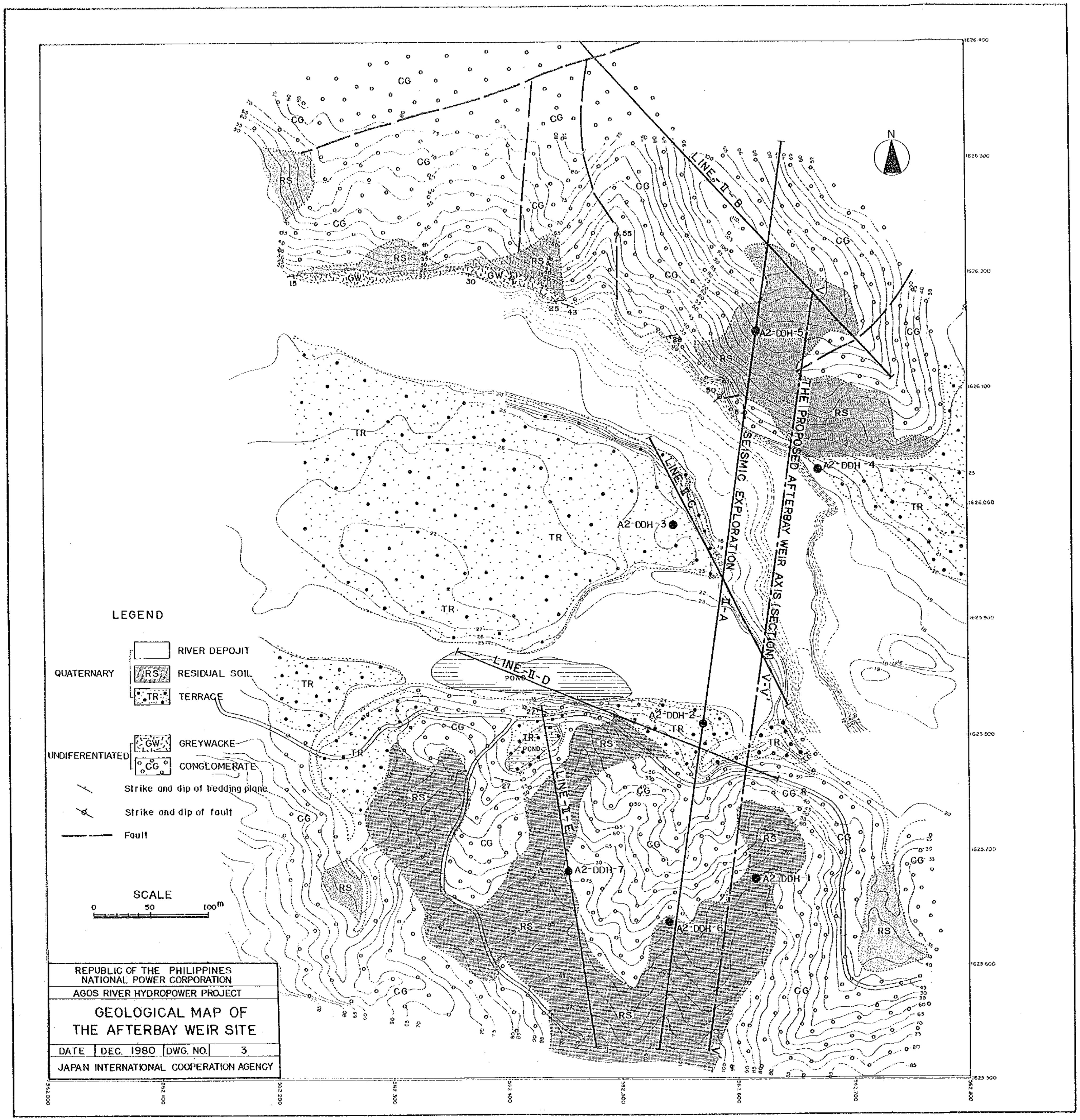
REPUBLIC OF THE PHILIPPINES
NATIONAL POWER CORPORATION

AGOS HYDROELECTRIC PROJECT

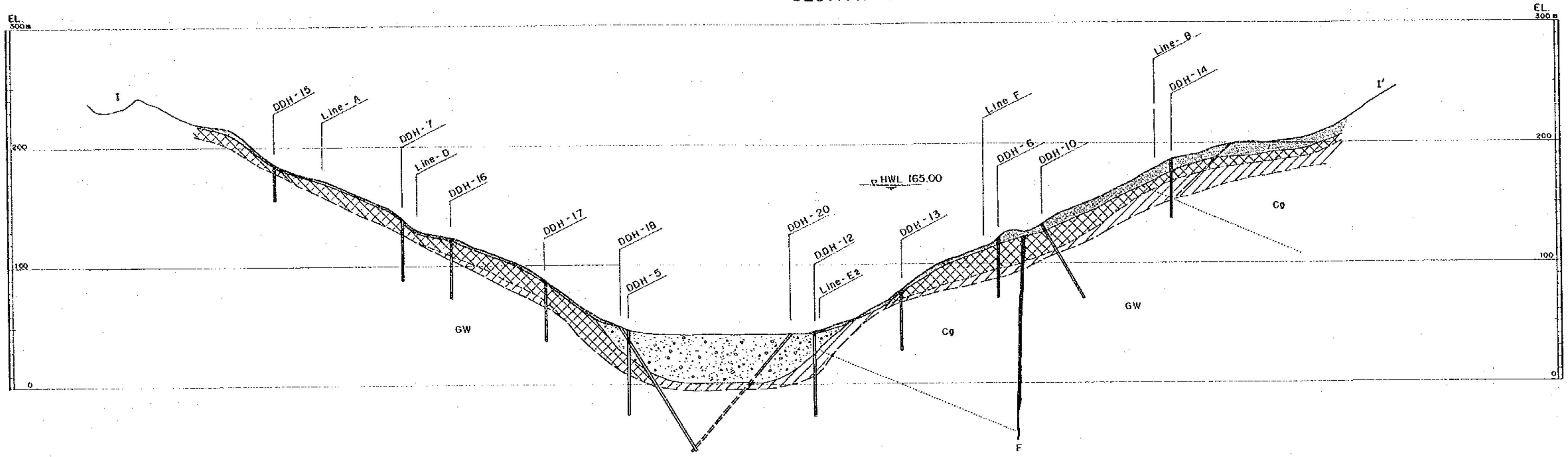
GEOLOGICAL MAP OF THE AGOS DAMSITE

DATE	DEC. 1980	DWG. NO.	2

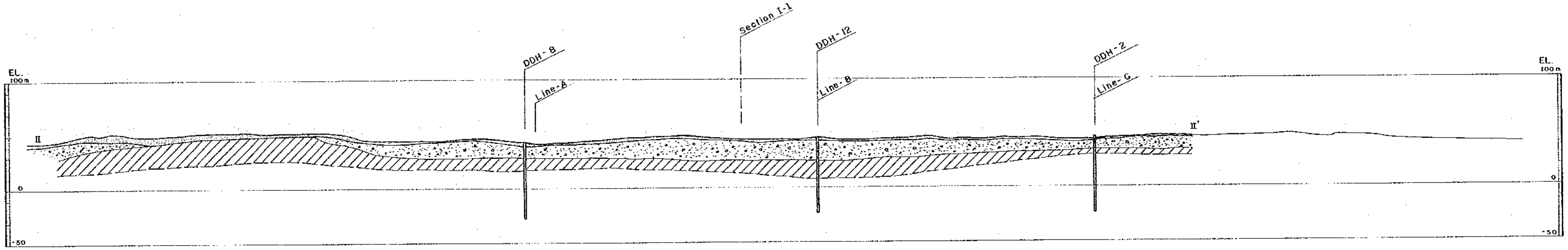
JAPAN INTERNATIONAL COOPERATION AGENCY


LEGEND
QUATERNARY
RIVER DEPOJIT
RS RESIDUAL SOIL
TR TERRACE
UNDIFERENTIATED
GW GREYWACKE
CG CONGLOMERATE
Strike and dip of bedding plane
Strike and dip of fault
Fault
SCALE
0 50 100m
LINE-II-B
LINE-II-C
LINE-II-D
LINE-II-E
SEISMIC EXPLORATION II-A
THE PROPOSED AFTERBAY WEIR AXIS (SECTION V-V)
A2-DDH-1
A2-DDH-2
A2-DDH-3
A2-DDH-4
A2-DDH-5
A2-DDH-6
A2-DDH-7
POND
N
REPUBLIC OF THE PHILIPPINES
NATIONAL POWER CORPORATION
AGOS RIVER HYDROPOWER PROJECT
GEOLOGICAL MAP OF
THE AFTERBAY WEIR SITE
DATE DEC. 1980 DWG. NO. 3
JAPAN INTERNATIONAL COOPERATION AGENCY

SECTION I-I'



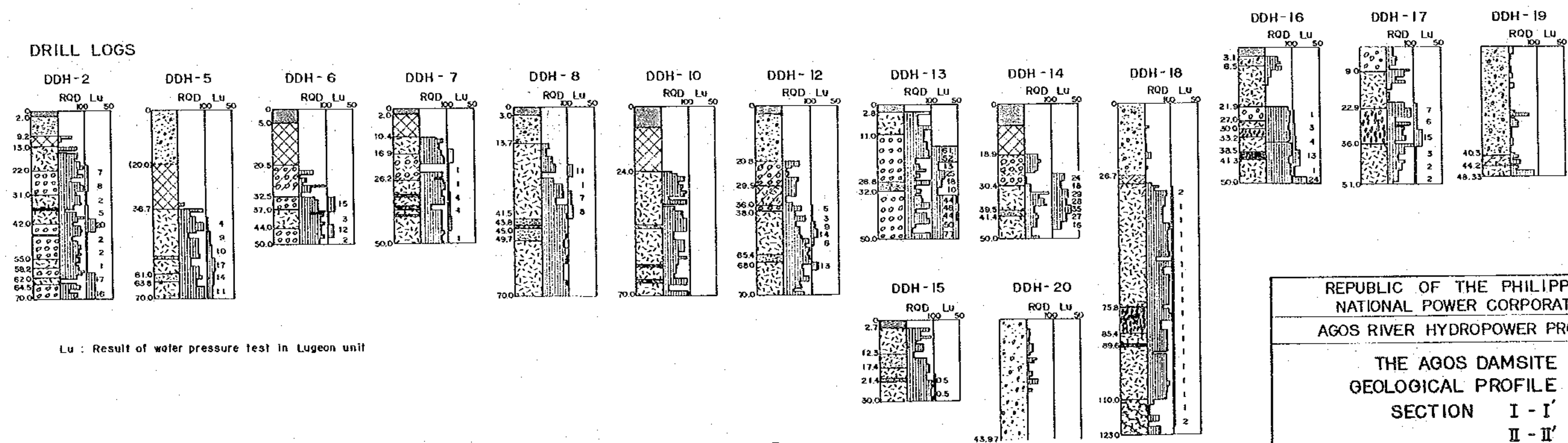
SECTION II-II'



LEGEND

- Top soil and talus deposit
- River deposit, sand and gravel
- Decomposed rock or residual soil
- Weathered rock
- Fresh rock
- Greywacke
- Conglomerate
- Fine-medium sandstone
- Calcareous breccia

DRILL LOGS

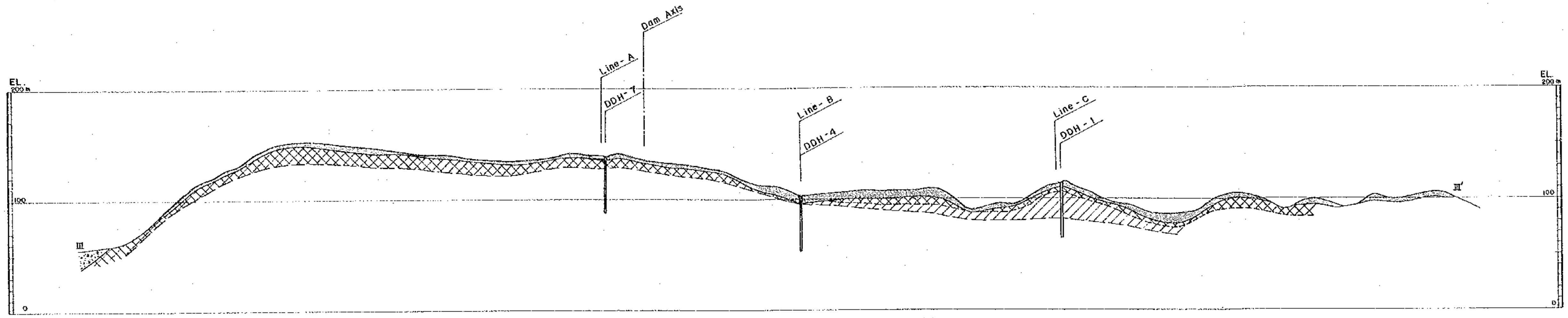


Lu : Result of water pressure test in Lugeon unit

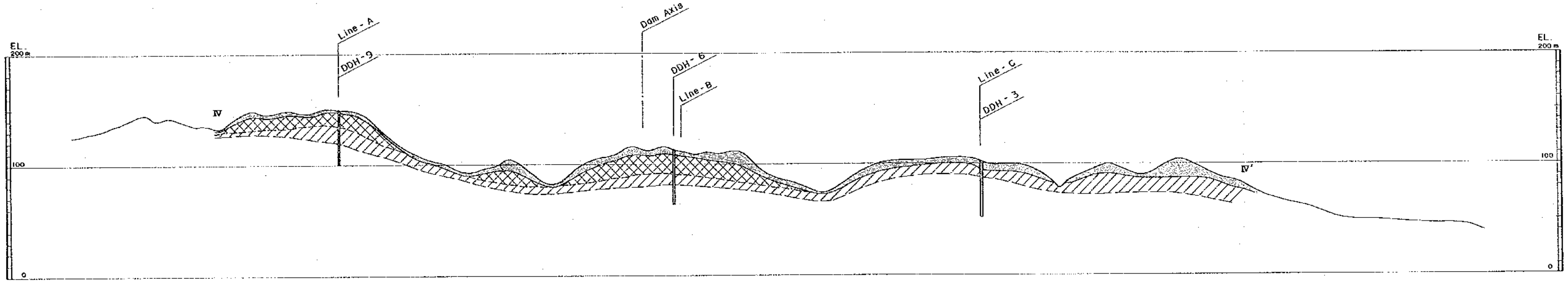
0 50 100m

REPUBLIC OF THE PHILIPPINES NATIONAL POWER CORPORATION			
AGOS RIVER HYDROPOWER PROJECT			
THE AGOS DAMSITE GEOLOGICAL PROFILE 1. SECTION I-I' II-II'			
DATE	DEC. 1980	DWG. NO.	4
JAPAN INTERNATIONAL COOPERATION AGENCY			

SECTION Ⅲ - Ⅲ'

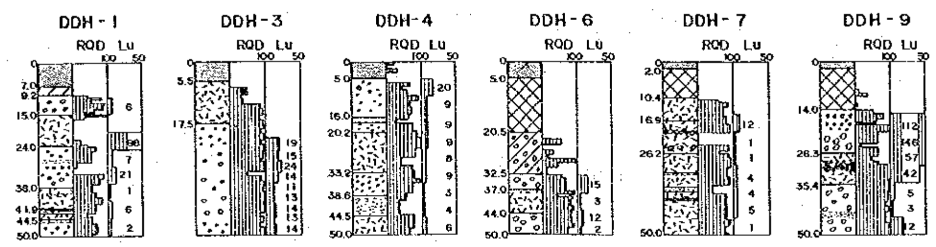


SECTION Ⅳ - Ⅳ'



LEGEND

- Top soil and talus deposit
- River deposit, sand and gravel
- Decomposed rock or residual soil
- Weathered rock
- Fresh rock
- Graywake
- Conglomerate
- Fine - medium sandstone

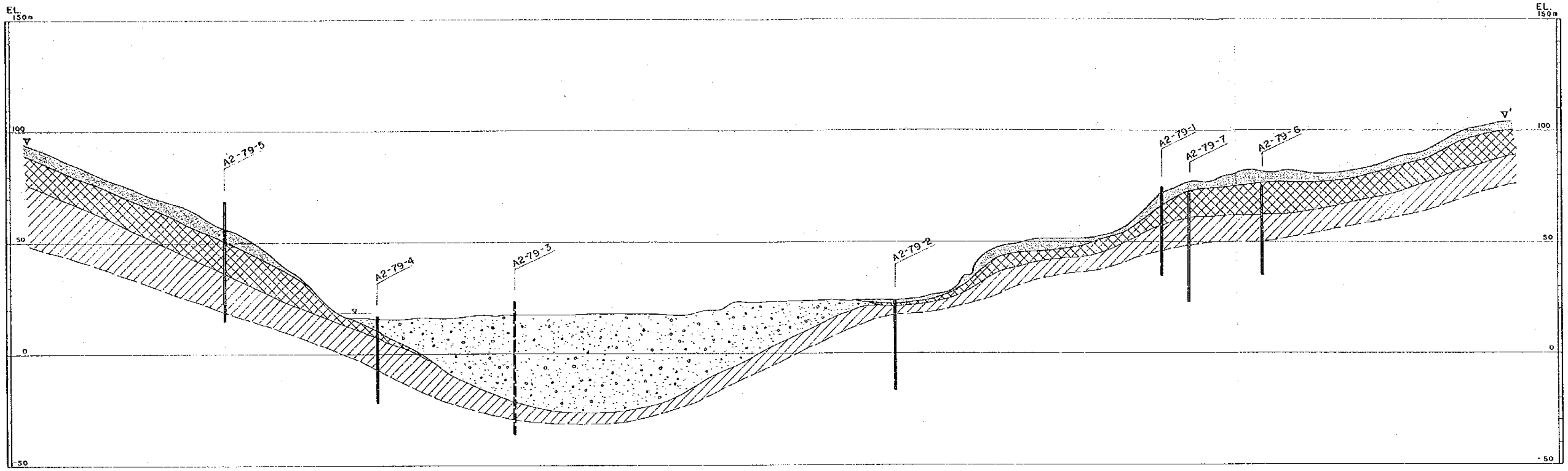


Lu : Result of water pressure test in Lugeon unit

SCALE 0 50 100 m

REPUBLIC OF THE PHILIPPINES NATIONAL POWER CORPORATION			
AGOS RIVER HYDROPOWER PROJECT			
THE AGOS DAMSITE GEOLOGICAL PROFILE 2 SECTION Ⅲ - Ⅲ' Ⅳ - Ⅳ'			
DATE	DEC. 1980	DWG. NO.	5
JAPAN INTERNATIONAL COOPERATION AGENCY			

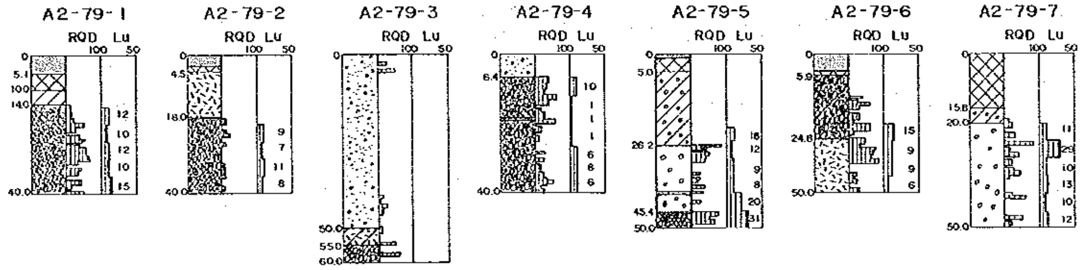
SECTION V-V'



LEGEND

- Top soil and talus deposit
- River deposit, sand and gravel
- Decomposed rock or residual soil
- Weathered rock
- Fresh rock
  - Graywacke
  - Conglomerate
  - Fine - medium sandstone
  - Calcareous breccia

DRILL LOGS



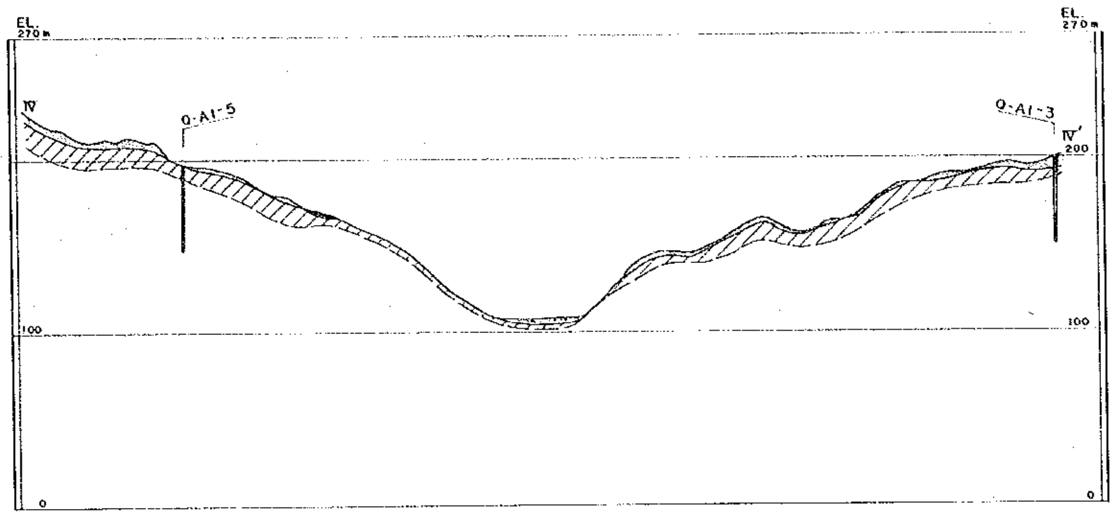
Lu : Result of Water Pressure test in Lugeon Unit.

SCALE

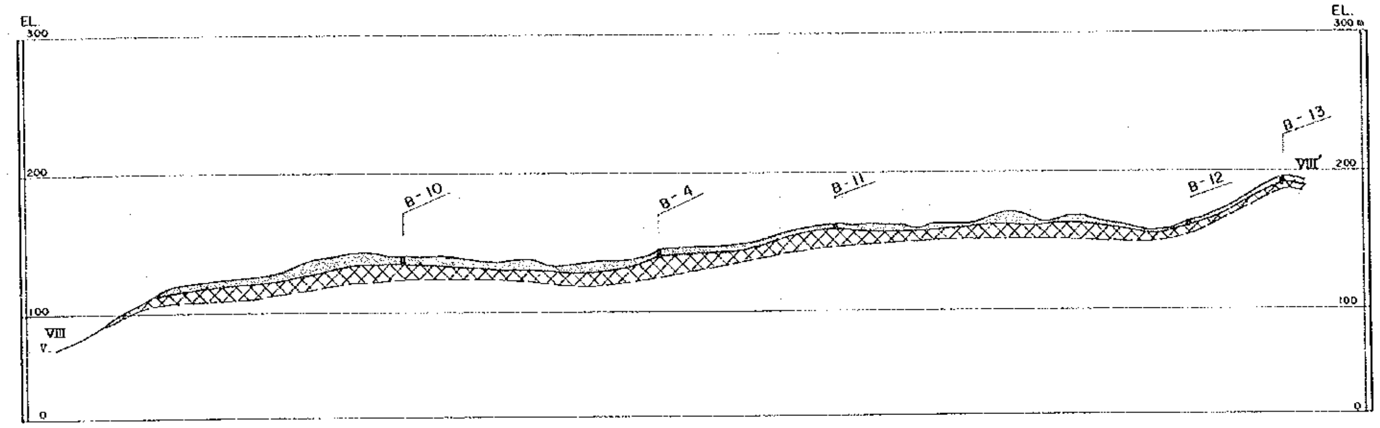
0 50 100m

REPUBLIC OF THE PHILIPPINES NATIONAL POWER CORPORATION			
AGOS RIVER HYDROPOWER PROJECT			
THE AFTERBAY WEIR SITE GEOLOGICAL PROFILE 3 SECTION V - V'			
DATE	DEC. 1980	DWG.NO.	6
JAPAN INTERNATIONAL COOPERATION AGENCY			

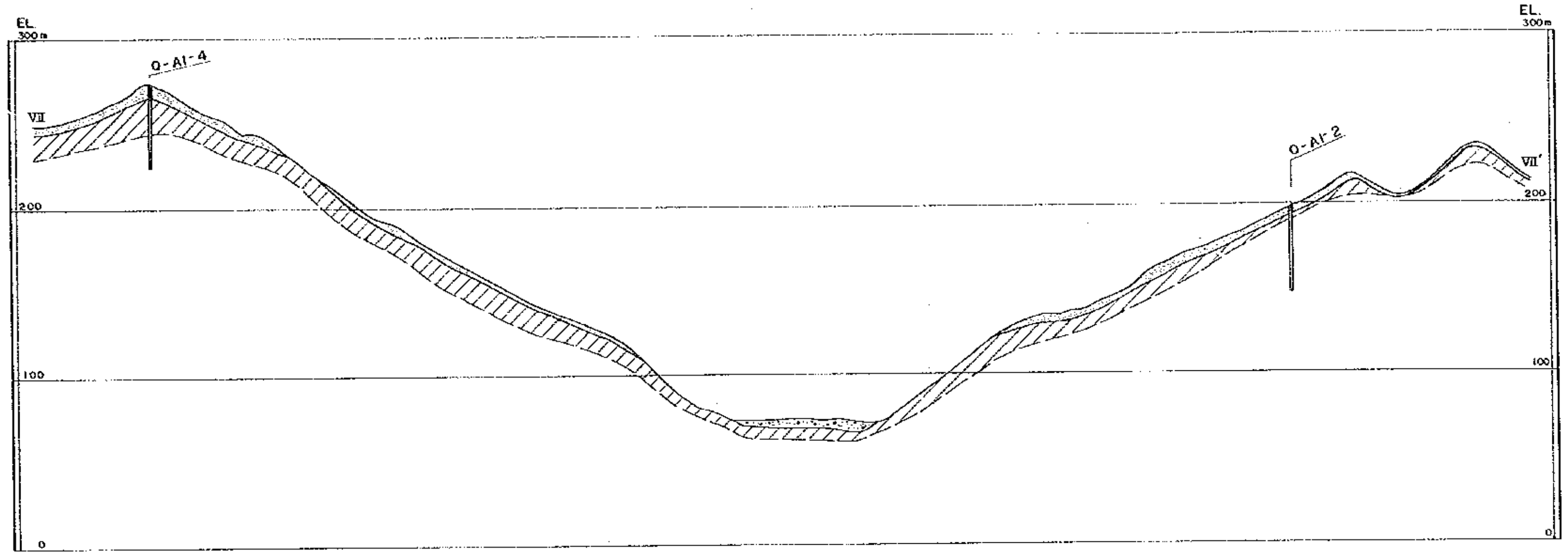
SECTION VI - VI'

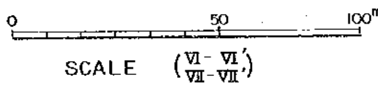


SECTION VIII - VIII'

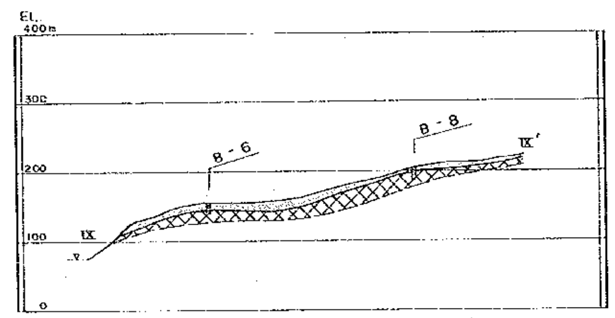


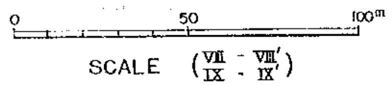
SECTION VII - VII'

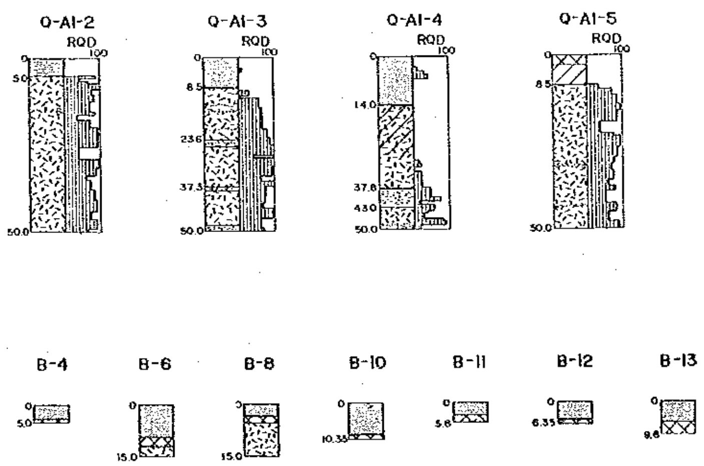




SECTION IX - IX







LEGEND

- Top soil and talus deposit
- River deposit, sand and gravel
- Decomposed rock or residual soil
- Weathered rock
- Fresh rock
- Greywacke
- Conglomerate

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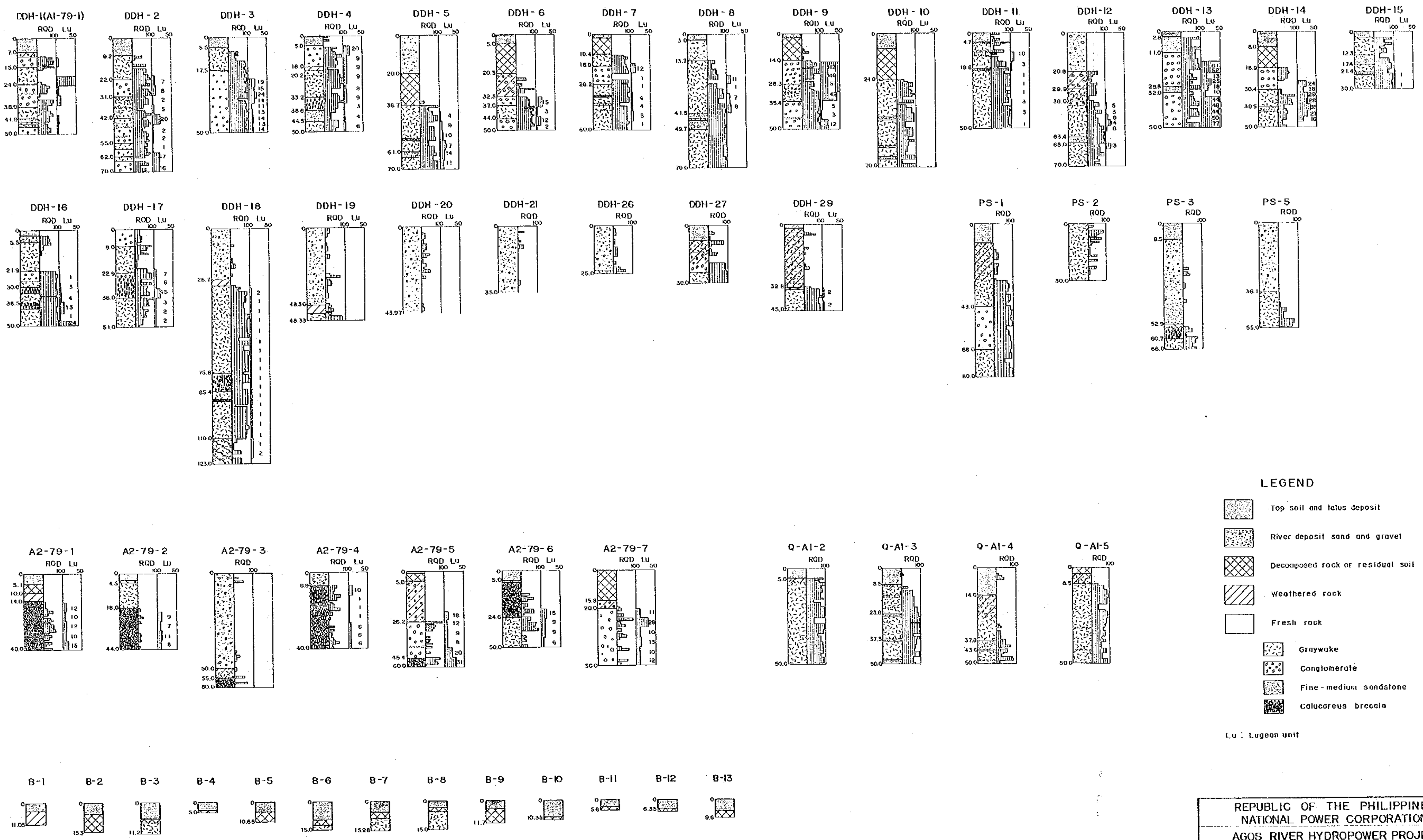
AGOS RIVER HYDROPOWER PROJECT			
QUARRY SITE & BORROW PIT GEOLOGICAL PROFIL 4 SECTION VI - VI' VII - VII' VIII - VIII' IX - IX'			
DATE	DEC. 1980	DWG. NO.	7
JAPAN INTERNATIONAL COOPERATION AGENCY			



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BORING LOGS

DATE	DEC. 1980	DWG. NO.	8

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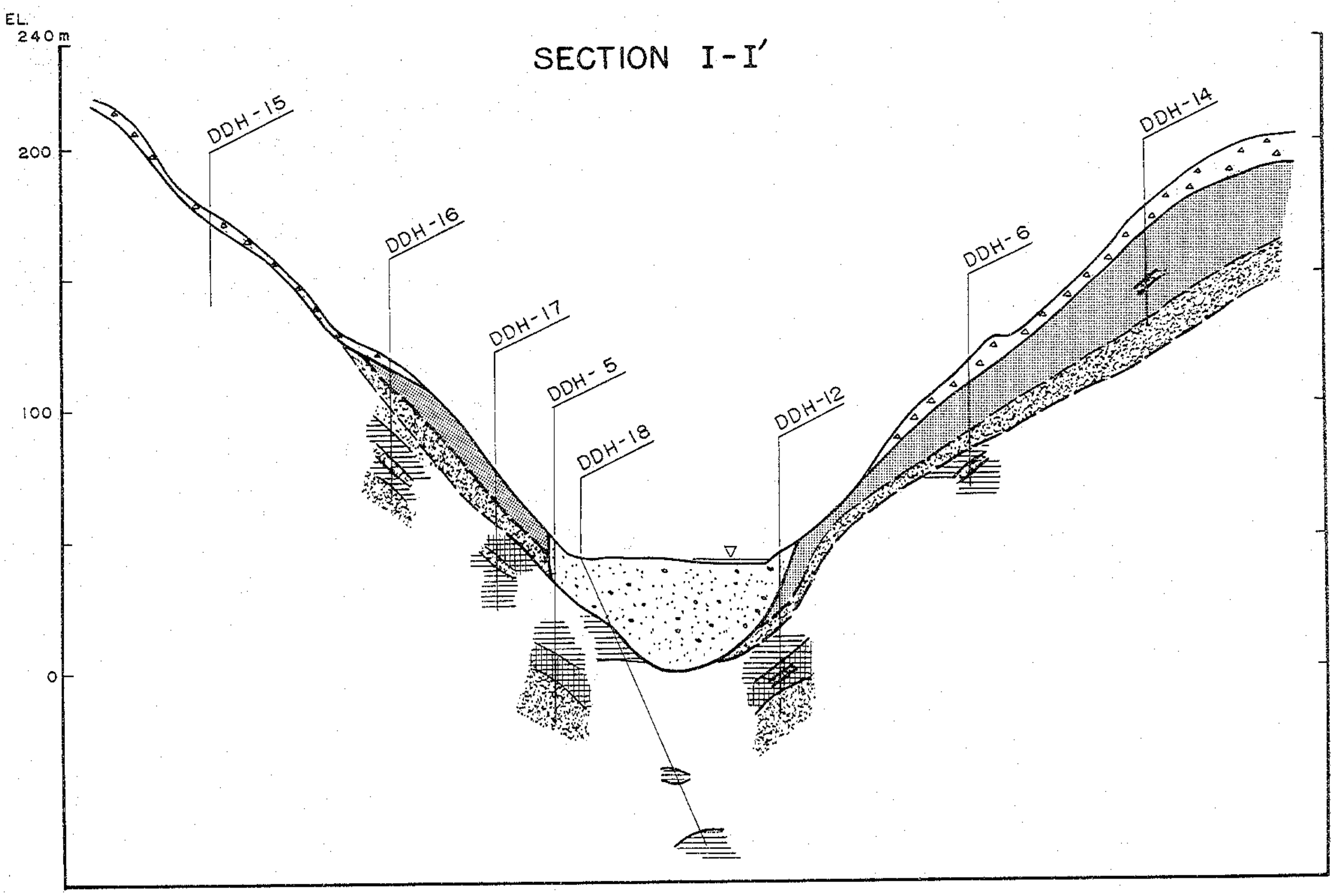

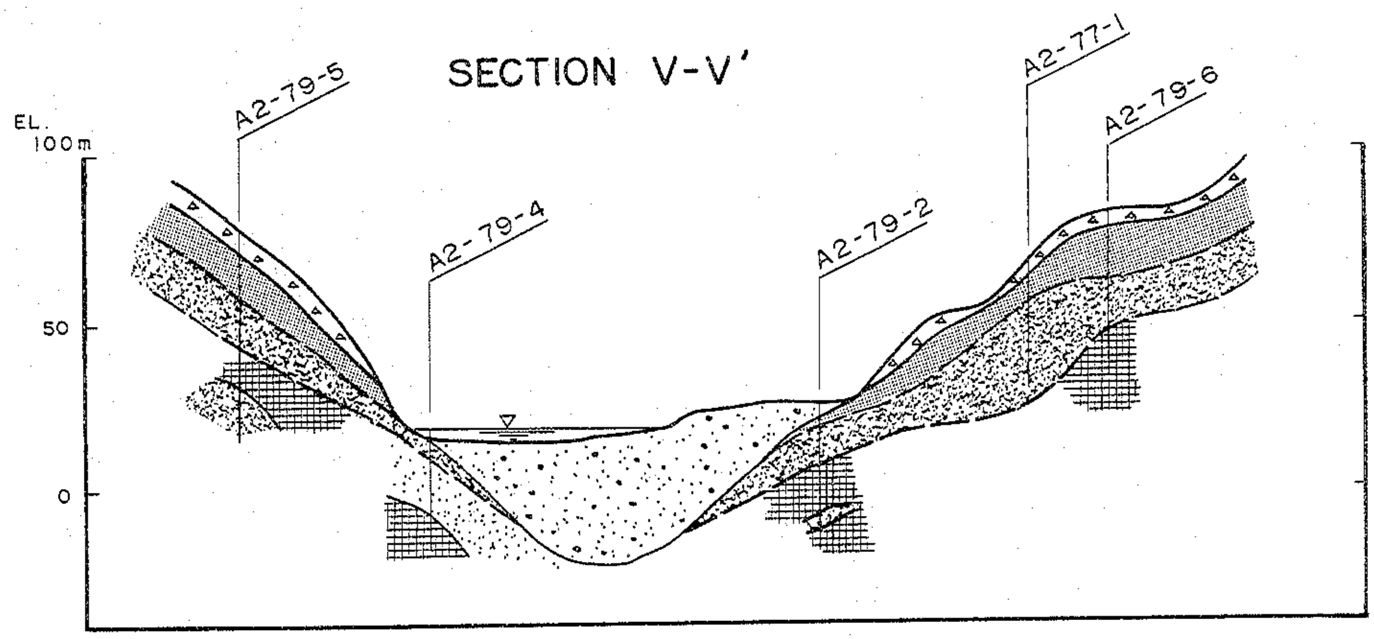

LEGEND

- $20 \leqq L$ (Lugoon Unit)
- $10 \leqq L < 20$
- $5 \leqq L < 10$
- $1 \leqq L < 5$
- $1 > L$
- Top soil and talus deposit
- River deposit

SCALE
0 100 200m

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PROFILE OF PERMEABILITY SECTION I-I′ SECTION V-V′			
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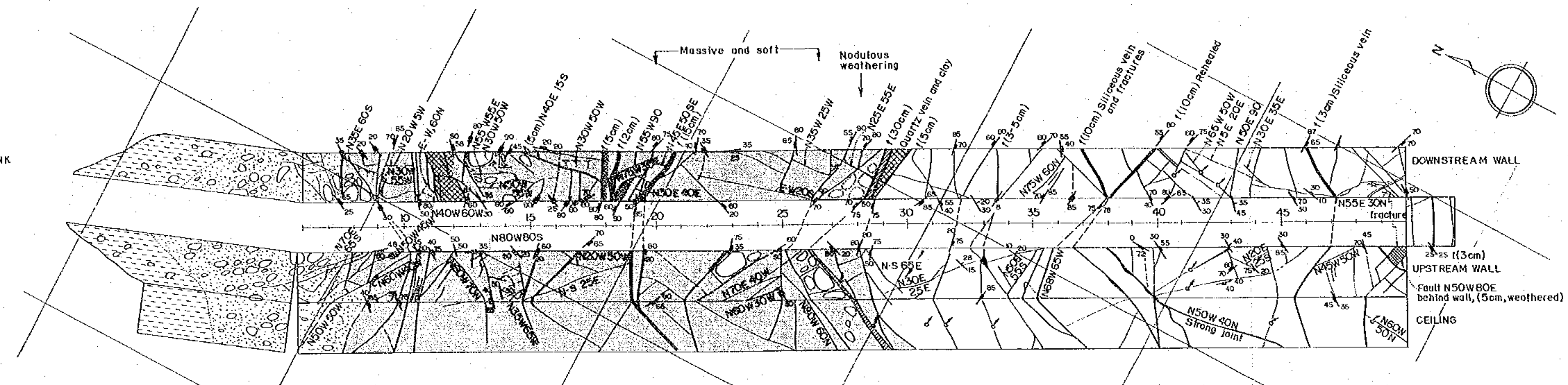


Reddish brown topsoil	Residual soil, containing round cobbles and boulders which remained as cores of nodulous weathering yellowish brown.	Intensively weathered conglomerate. Included gravels are greywacke and volcanic rocks. Matrix is greywacke type sandstone, some tuffaceous. No much difference of hardness between gravel and matrix.			Greywacke Sandstone, chloritized.		
		Soft rock with joints at 10-20 cm intervals. Some cracks are open and filled with clay ; the most are closed.	Soft rock, Joints spacing 10-15cm closed cracks.	Soft rock Massive. Joints are rather sparse Cracks are closed The faults are minor ones compactly packed with sand-clay and calcite and quartz veins.	Soft rock, with nodular weathering.	Fresh rock. Hard and solid. Joints are spaced more than 30cm ~ 50cm. Cracks are closed.	Cracks are rather fragmental

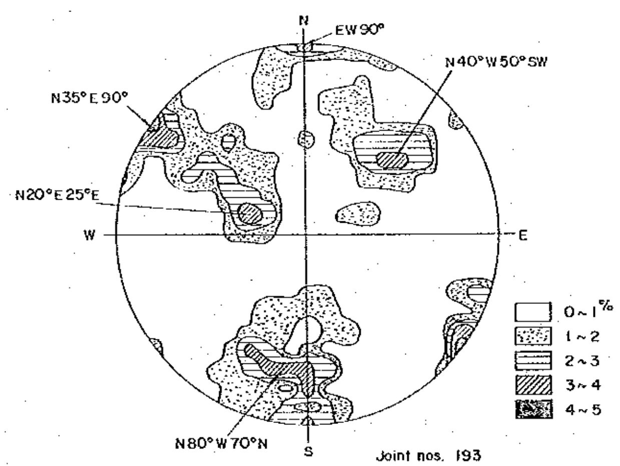
Gradually changes from residuum to weathered rock.

Sharply changes from intensively weathered rock to fresh rock with a fault for boundary.

SCALE

0 5 10 m

EQUAL AREA STEREOGRAPHIC PROJECTION
FOR THE FREQUENCY OF JOINT DIRECTION



(Polars points of joint planes are plotted on the lower hemisphere.)

LEGEND

- Reddish brown loam with gravels
- Residual soil
- Intensively weathered rock
- Fractured or loose
- Fresh rock
- Seepage
- Cleavages (Joint, dislocation Plane, bedding plane) with calcite or quartz veins.
- Cleavages without veins.
- Strike and dip of dislocation plane and joint
- Strike and dip of bedding plane
- f(5cm) Fault and its width.

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AGOS RIVER HYDROPOWER PROJECT			
GEOLOGICAL MAP TEST ADIT NO.1			
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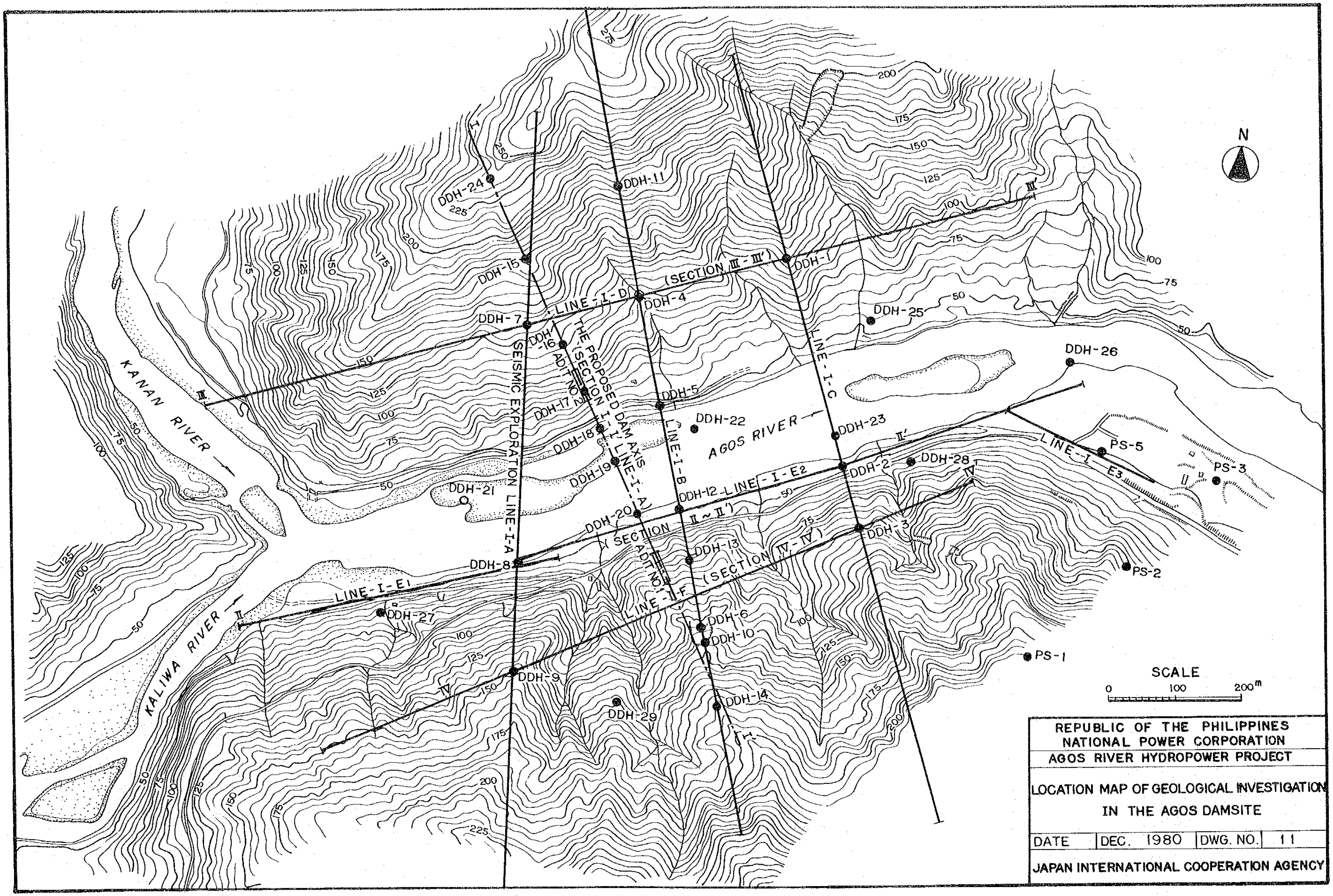

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LOCATION MAP OF GEOLOGICAL INVESTIGATION IN THE AGOS DAMSITE

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